Lying behavior and postpartum health status in grazing dairy cows

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ABSTRACT

Many cows have difficulty making the transition from pregnancy to lactation, as evidenced by the high incidence of disease that occurs in the weeks after calving. Changes in lying behavior can be used as an indicator of illness, yet no work to date has evaluated this relationship in dairy cows on pasture. The objectives of this study were to describe the lying behavior of grazing dairy cows during the first 3 wk after calving and determine the relationships between transition diseases and lying behavior. Our convenience sample included 227 multiparous and 47 primiparous Holstein cows from 6 commercial farms. Cows were recruited as they calved during the spring calving period. Electronic data loggers (Hobo Pendant G Acceleration, Onset Computer Corp., Pocasset, MA) recorded lying behavior at 1-min intervals. Diseases were recorded up to 21 d in milk, and cows were subsequently categorized into 3 health categories: (1) healthy, not lame and had no other signs of clinical (retained placenta, milk fever, metritis, mastitis) or subclinical (ketosis, hypocalcemia) postpartum diseases; (2) lame, identified as being clinically or severely lame with no other signs of clinical or subclinical postpartum disease; and (3) sick, diagnosed as having one or more clinical postpartum diseases (with or without a subclinical disease) but not lame. This last group was further divided into 2 groups: those that were diagnosed with a single clinical health event and those diagnosed with more than one clinical event. Lying behavior differed between primiparous and multiparous cows; primiparous cows divided their lying time into more bouts than did multiparous cows (9.7 ± 0.54 vs. 8.4 ± 0.26 bouts/d) and spent less time lying down than multiparous cows (7.5 ± 0.38 h/d vs. 8.5 ± 0.19 h/d). Lying behavior was also affected by illness; primiparous cows that developed more than one clinical disease, excluding lameness, spent more time lying, and tended to have longer lying bouts in the days following calving compared with healthy cows; multiparous

severely lame cows spent more time lying down (1.7 h longer per day) compared with multiparous cows that were nonlame. Clinically lame cows had fewer lying bouts per day and these bouts were of longer duration than healthy nonlame cows. In summary, changes in lying behavior after calving were associated with postpartum health status in grazing dairy cows.

Key words: transition, pasture, illness, lameness

INTRODUCTION

Cows are at a high risk for both metabolic and infectious diseases in the weeks following parturition (Ingvarsen et al., 2003; Mulligan and Doherty, 2008). Traditional methods for detecting diseases on farms rely on visual observation of the animals and the use of additional testing on blood, urine, or milk if needed. However, the absence of external symptoms of some diseases and a low level of individual monitoring of cows in many large farms likely results in many sick cows going unnoticed (Weary et al., 2009).

Changes in behavior can indicate pain and malaise associated with poor health, and may also predict animals at risk for disease (reviewed by Weary et al., 2009). More specifically, changes in standing and lying behavior can be a useful indicator of some common health problems occurring during the transition period, such as lameness (Proudfoot et al., 2010; Calderon and Cook, 2011), dystocia (Proudfoot et al., 2009), and subclinical hypocalcemia (Jawor et al., 2012). The majority of work to date on transition cow behavior has focused on cows in freestall housing, with little research in pasture-based systems.

The type of housing provided to dairy cattle can affect standing and lying behavior of dairy cows (e.g., Krohn and Munksgaard, 1993; Olmos et al., 2009; Navarro et al., 2013). Cows on pasture spend more time standing (Hernandez-Mendo et al., 2007; Legrand et al., 2009) and walking to and from pasture to be milked (Stafford and Gregory, 2008).

Lying behavior is also influenced by stage of lactation. For instance, lying time and lying bout duration increase with increasing DIM (Munksgaard et al., 2005; Vasseur et al., 2012; Ito et al., 2014). The increased

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energy demands resulting from lactation in the weeks after calving may be met through increased feed intake, but this requires more time spent feeding. This increase will likely be higher in grazing systems than in indoor housing where cows are fed energy-rich diets, resulting in less time lying down (Nielsen et al., 2000; Dohme-Meier et al., 2014). For these reasons, lying behavior of transition cows on pasture may not be comparable to transition cows in indoor housing.

Lying behavior can be continuously and automatically monitored using tridimensional accelerometers (e.g., Ledgerwood et al., 2010). To our knowledge, no work has described the lying behavior of pasture cows in the critical weeks following parturition. The aims of our study were to (1) describe the lying behavior of grazing dairy cows on commercial farms during the first 3 wk after calving, and (2) determine the relationships between transition diseases and lying behavior after calving.

MATERIALS AND METHODS

Cows and Farm Management

The University of British Columbia Animal Care Ethics Committee (Canadian Council on Animal Care, 2009) approved the methods described within the present study. Our study was conducted between July and December 2012 on 6 spring-calving commercial dairy farms located in the southern province of Osorno, Chile (40°34'S, 73°9'W). The number of farms included was determined predominantly by time constraints as the maximum number that could be recruited and assessed within the spring calving period. One local feed supplier was asked to select 6 of their clients that met the following criteria: pasture housing, milking >200 cows, use predominantly Holsteins, and willing to participate in the proposed protocol. Average herd size was 302 $\pm$ 54 ($\pm$ SD, ranging from 254 to 379) milking cows producing 8,730 $\pm$ 1,090 (ranging from 7,329 to 9,650) kg annually (based on annual yield estimates).

Two hundred seventy-four cows (47 primiparous and 227 multiparous) were enrolled in the study with a median (range) parity of 3.0 (1 to 9) and a median (range) BCS at calving of 3.25 (2 to 4). During the late-winter months of August and September, 15 and 26 cows were recruited, respectively. In the spring months of October and November, 123 and 110 cows were recruited. The mean $\pm$ SD number of cows enrolled per farm was 45.7 $\pm$ 9.4, with a range across all farms from 30 to 55 cows.

Transition period management consisted of a 60-d average dry period, where cows were moved from the far-dry group to the close-up group 24 $\pm$ 8.7 d (mean $\pm$ SD) before expected due date. Cows in the close-up

group were kept on paddocks (5 farms) or in an enclosed barn (1 farm), both without access to fresh pasture. On all farms, the close-up diet included a professionally formulated, commercially produced anionic transition supplement fed with hay and chopped straw. On all farms, immediately after calving, cows were moved to the lactating cow group and managed in a daily rotational grazing system typical for this region, thus providing adequate daily forage intake. Cows grazed a perennial ryegrass-dominant pasture (*Lolium perenne*) that provided, on average, approximately 70% of the daily energy intake. Concentrates (approximately 4–6 kg per cow per day) and a mineral mix (offered with the concentrate) were fed in the milking parlor during morning and afternoon milking. All animals were milked twice daily, with milking times between 0500 and 0800 h and between 1500 and 1800 h, depending on the farm management.

With the exception of when they were being milked, all cows were housed continuously on pasture throughout the duration of the study. The mean ($\pm$ SD) air temperature during the study was 9.9 $\pm$ 2.6, ranging from -4.1 to 25.6°C, with a mean ($\pm$ SD) relative humidity of 81.8 $\pm$ 6.5%. Although we did not measure the amount of shade cover, all paddocks that were used during the course of this experiment had trees along parts of the perimeter fences or, in some cases, single trees dispersed within the paddock. We did not observe any competition among cows for shade or lying space.

Data Collection

Cows were enrolled systematically based on the availability of the data-recording devices. Body condition score (1 to 5, following Edmonson et al., 1989) was evaluated on the day of calving. Diseases occurring during the first 24 to 72 h after calving, including retained placenta and milk fever, were recorded by farm staff on each of the farms using previously established case definitions. Retained placenta was defined as failure to expel the placenta within 24 h after parturition. Clinical milk fever was defined as any recumbent cow within 72 h after parturition exhibiting anorexia, nervous symptoms, staggering, varying degrees of unconsciousness, and good response to intravenously administered calcium. In addition, from calving to 21 DIM, all cows were evaluated twice daily at the start of milking for signs of clinical mastitis by the milker. Clinical mastitis was characterized by the presence of abnormal milk or by signs of inflammation in 1 or more quarters.

Starting at d 3 until 22 $\pm$ 1 after calving, cows were monitored for metritis twice weekly, with 2 or 3 d between visits by a single, trained veterinarian, using a manual vaginal examination and vaginal discharge

(VD) score (following Huzzey et al., 2007). Appearance and smell of the VD was evaluated and assigned one of the following categories: no mucus or clear mucus (0); cloudy mucus or mucus with flecks of pus (1); mucopurulent ($\leq 50\%$ pus present) and foul smelling (2); purulent ($\geq 50\%$ pus present) and foul smelling (3); and putrid (red or brown color, watery, foul smelling; 4). Cows were classified as having severe metritis if they had at least one VD score of 4 and one recording of fever ($\geq 39.5^\circ\text{C}$). Cows were classified as having mild metritis if they had at least one VD score of 2 or 3 and no VD score of 4, with or without fever. During these health checks, any presence of other clinical disease(s) was recorded.

Additionally, on d 22 ± 1 after calving, cows were locomotion scored as they exited the parlor using a 5-point numerical rating system (NRS), where 1 = sound and 5 = severely lame (Flower and Weary, 2006). Lameness was categorized as clinical lameness (prevalence of cows scored as NRS = 3) and severe lameness (prevalence of cows scored as NRS = 4). No cow was scored as NRS = 5. With the exception of the diagnoses for retained placenta, milk fever, and mastitis, the same trained veterinarian evaluated all other diseases, including lameness.

Blood samples were collected postpartum between d 3 to 7 to represent wk 1, d 8 to 14 to represent wk 2, and d 15 to 22 ± 1 to represent wk 3. Blood was collected from the coccygeal vessel into 10-mL sterile tubes coated with sodium heparin and then stored in coolers until they could be returned to the laboratory for processing. Plasma was harvested after centrifugation ($2,000 \times g$ for 15 min at 4°C) and stored at -20°C for later analyses. Concentrations of BHBA (Ranbut, Randox, Crumlin, United Kingdom) was measured by enzymatic analysis using an autoanalyzer (Metrolab 2300, Wiener Lab, Rosaria, Argentina). Intra- and interassay CV were 2.8 and 4.7%, respectively. Concentrations of calcium were determined using an atomic absorption spectrophotometer (Solar Series S, Thermo Scientific Electron Corporation, Waltham, MA). Intra- and interassay CV for the calcium were 2.7 and 3.5%, respectively. Subclinical ketosis was diagnosed when plasma BHBA concentration was >1.2 mmol/L (Ospina et al., 2010) in at least 1 of the 3 samples. Subclinical hypocalcemia was defined when plasma calcium was <2.0 mmol/L in at least 1 of the 3 samples (Goff, 2008).

Health Status Classification

Cows were divided retrospectively into 3 groups for statistical analyses: (1) healthy cows, including all cows that were not diagnosed as having clinical or severe

lameness or any other clinical postpartum disease, such as retained placenta, milk fever, metritis, mastitis, or subclinical ketosis or hypocalcemia; (2) lame cows, including only cows that were identified as being clinically or severely lame, with no other clinical or subclinical postpartum disease; and (3) sick cows, including cows that were diagnosed as having one or more clinical maladies (e.g., retained placenta, metritis, or mastitis) with or without a subclinical disorder (e.g., ketosis or hypocalcemia) but were not lame. This last group was further divided into 2 groups: those that were diagnosed with a single clinical health event and those diagnosed with more than one clinical event. Cows that showed signs of systemic health problems (e.g., anorexia, depression), such as from milk fever ($n = 10$), clinical ketosis ($n = 5$), acute clinical mastitis ($n = 7$), and displaced abomasum ($n = 3$), were not included in the analyses. In addition, cows that were lame and presented clinical or subclinical diseases were also excluded from the final analyses ($n = 15$).

Lying Behavior Collection

Lying behavior was collected using dataloggers (Hobo Pendant G Acceleration Data Logger, Onset Computer Corporation, Pocasset, MA) attached to the hind leg of each cow using a flexible bandage. Every 10 d, loggers were removed for data download and then reattached to the leg. The loggers were programmed to record the tilt of the leg in 3 axes at 1-min intervals. This information was used to determine whether the cow was standing or lying, and subsequently used to calculate total lying time, number of lying bouts (i.e., frequency of transitions from lying to standing positions), and duration of lying bouts per day (i.e., calculated as a ratio of minutes lying to the number of lying bouts per day).

Statistical Analysis

Statistical analyses were performed using SAS software (version 9.3; SAS Institute Inc., Cary, NC) with cow as the experimental unit. Lying behavior data were summarized by cow and day to obtain daily total lying time, number of lying bouts, and average lying bout duration. As data loggers were attached to each cow within 1 or 2 d after calving, d 1 and 2 were not considered in any of the analyses as the full daily data were not available for all cows.

To describe the lying behavior of grazing cows after calving, we used data collected from healthy cows. Lying time, lying bouts, and lying bout duration data were analyzed using mixed models with repeated measures over cow (PROC MIXED), considering farm as a random effect, day relative to calving, parity (primipa-

rous and multiparous), and calving month (August, September, November, and December) as fixed effects, and the interaction of day $\times$ parity. The covariance structure selected was compound symmetry based on the lowest Akaike's information criterion. Because of significant day $\times$ parity interaction for lying time ($P = 0.001$), these data were stratified by parity.

An exploratory analysis showed that the greatest changes in lying behavior in cows that developed one or multiple clinical events (sick cows) occurred during the first few days after calving; thus, we focus for the analyses on d 3 to 7. Data were analyzed using mixed models, as described previously, including health status (healthy, 1 event, >1 event) as fixed effects, and the interactions of day and parity $\times$ health status. Because of the significant parity $\times$ day interaction for lying time ($P = 0.001$), data were stratified by parity. After visual inspection of the graphs, differences were noted and specific contrasts were made between health categories (healthy vs. 1 event or healthy vs. >1 event) on d 3 and d 4 separately using the ESTIMATE statement of PROC MIXED.

To determine the change in lying behavior between lame and healthy cows, data were analyzed using mixed models with repeated measures over cow as previously described. The model included lameness status (healthy, clinical lame, severe lame) and the interactions of lameness status $\times$ day. No primiparous cows developed lameness without another postpartum disease; therefore, only multiparous cows were included in the analyses. These analyses showed that only the effect of lameness status was significant for all behaviors ($P \leq 0.04$); specific comparisons were made between healthy and clinical lame cows as well as healthy and severely lame cows using the ESTIMATE statement.

In all models, residuals were examined after to verify normality and homogeneity of variances and to detect possible outliers and influential points. No observations were removed from the analyses.

RESULTS

Descriptive Data

Of the 249 cows included in the study, 119 (primiparous, $n = 16$; multiparous, $n = 103$) did not present any clinical (retained placenta, milk fever, metritis, mastitis, lameness, or other clinical health event) or subclinical (ketosis or hypocalcemia) postpartum disease and were classified as healthy. All other cows developed a single case or multiple cases of postpartum clinical disease (Table 1). The mean ($\pm$ SD) days postpartum at diagnosis of the first case of severe and mild metritis were 4.2 ± 0.5 and 5.9 ± 0.7 , respectively.

Lying Behavior of Grazing Cows

The average daily lying time was 7.5 ± 0.38 h/d for primiparous cows versus 8.5 ± 0.19 h/d for multiparous cows ($P < 0.001$). Lying time did not change in the days after calving for multiparous cows (slope: 0.01 ± 0.01 ; $P = 0.31$), but primiparous cows gradually increased their lying times over this period (slope: 0.06 ± 0.02 ; $P = 0.01$; Figure 1a).

Primiparous cows divided their lying time into more bouts than did multiparous cows (9.7 ± 0.54 versus 8.4 ± 0.26 bouts/d; $P = 0.02$), but this behavior did not change over time for either parity ($P = 0.16$; Figure 1b). The duration of lying bouts was lower for primiparous versus multiparous cows (50.8 ± 3.52 vs. 63.4 ± 1.72

Table 1. Frequency (no.) of health disorders during the first 21 DIM by parity (PP, primiparous; MP, multiparous) in the experimentally defined health categories

Health disorder	Total events	One clinical event ¹		More than one clinical event ²	
		PP (n = 20)	MP (n = 42)	PP (n = 9)	MP (n = 17)
Retained placenta	17	0	0	4	13
Clinical mastitis	14	1	1	5	7
Severe metritis	33	4	11	5	13
Mild metritis	53	15	30	3	5
Subclinical hypocalcemia	21	0	16	0	5
Subclinical ketosis	28	4	14	1	7
Clinical lameness ³	17	—	—	—	—
Severe lameness ³	10	—	—	—	—

¹One clinical event = cows that developed only 1 clinical disorder (retained placenta, mastitis, or metritis, excluding lameness) with or without a subclinical disorder (hypocalcemia or ketosis).

²More than one clinical event = cows that developed 2 or more clinical disorders (retained placenta, mastitis, or metritis, excluding lameness) with or without a subclinical disorder (hypocalcemia or ketosis).

³Cows that developed only lameness (with no clinical or subclinical event) were included as a separate group for the analyses.

Figure 1. Changes in least squares means ($\pm$ SE) of daily lying time (A), number of daily lying bouts (B), and lying bout duration (C) of primiparous (PP; $n = 16$) and multiparous (MP; $n = 103$) grazing Holstein cows from 3 to 21 DIM.

min, respectively; $P = 0.005$) and, again, the behavior did not change over time for either parity ($P = 0.28$; Figure 1c).

Lying Behavior and Postpartum Diseases

A health status $\times$ day interaction was seen for the lying time in primiparous cows (Figure 2a; $P = 0.01$), but not for multiparous cows (Figure 2c; $P = 0.87$), during d 3 to 7 after calving. Primiparous cows that developed >1 clinical disease, excluding lameness, spent more time lying ($P = 0.04$) and tended to have longer lying bouts (Figure 2b; $P = 0.09$) during d 3 and 4 compared with healthy cows. The number of lying bouts did not differ between healthy cows or those that developed 1 or >1 disease after calving (primiparous = 9.7 ± 1.7 , 9.4 ± 0.7 , and 9.2 ± 0.9 bouts/d, respectively; multiparous = 8.5 ± 0.1 , 8.4 ± 0.2 , and 8.8 ± 0.3 bouts/d, respectively).

Lying Behavior and Lameness

On average, severely lame cows lay down 1.7 h longer per day ($P < 0.001$) and tended to have more lying bouts per day ($P = 0.09$) compared with healthy, non-lame cows (Figure 3a,b). Clinically lame cows had fewer lying bouts per day ($P = 0.04$), and these bouts were of longer duration ($P = 0.01$) than healthy, nonlame cows (Figure 3b,c).

DISCUSSION

Lying Behavior of Grazing Cows

To our knowledge, this is the first study to investigate lying behavior in transition cows on pasture. Previous reports on lying behavior in the weeks after calving have used cows housed indoors (Dechamps et al., 1989; Huzzey et al., 2005; Calderon and Cook, 2011; Steensels et al., 2012). The average lying times recorded in our study (7.5 and 8.5 h/d for healthy primiparous and multiparous cows, respectively) were lower than the values reported for transition cows housed in freestall (9.8–10.8 h/d; Huzzey et al., 2005; Calderon and Cook, 2011), tiestall (11.6 h/d; Dechamps et al., 1989), and indoor loose housing systems (9.6 h/d; Steensels et al., 2012). These differences in lying times are consistent with previous studies using mid- to late-lactation cows that also reported lower lying times for cows on pasture (Krohn and Munksgaard, 1993; Legrand et al., 2009; Olmos et al., 2009). On pasture, time required for grazing and walking depends on accessibility of forage (reviewed by Gregorini, 2012) and distance to the milking parlor; these activities can reduce the time available to perform other behaviors, such as lying (Munksgaard et al., 2005).

The postpartum cows in the current study had fewer lying bouts, of longer duration, compared with freestall-

Figure 2. Lying time and lying bout duration (LSM $\pm$ SE) in primiparous (A, B; $n = 45$) and multiparous (C, D; $n = 162$) grazing Holstein cows that were healthy and developed one clinical event or more than one clinical event from 3 to 7 DIM. Different ($\dagger P < 0.1$; $*P < 0.05$) from healthy cows and cows with more than one event.

housed cows at the same stage of lactation (12–15 lying bouts and 30–40 min/bout; Calderon and Cook, 2011). This finding suggests that, under the conditions of our study, cows find pasture to be a more comfortable surface for lying relative to the mattresses used in a previous freestall study. However, other work has reported shorter (about 40 min/bout) and more frequent lying bouts (15 bouts/d) for mid-lactation cows on pasture (Hernandez-Mendo et al., 2007). We suggest that the

relative comfort of pasture versus indoor housing is context dependent.

Primiparous cows had lower daily lying times during the first week after calving. These values increased during the second week and reached lying times similar to multiparous cows by the third week (average 7.0, 7.3 and 8.1 h/d, respectively). Previous studies have also found that first parity cows increase lying time with DIM, explained in large part by an increase in bout

Figure 3. Figure 3. Least squares means (+ SE) of lying time (A), lying bouts (B), and lying bout duration (C) of healthy (sound; $n = 103$), clinically lame (CL; $n = 17$), and severely lame (SL; $n = 10$) multiparous grazing Holstein cows at 3 and 21 DIM. Different ($†P < 0.1$; $*P < 0.05$; $***P < 0.001$) from sound cows.

duration (Nielsen et al., 2000; Bewley et al., 2010; Vasseur et al., 2012). In our study, the frequency of lying bouts was higher and the bout duration was shorter for primiparous cows compared with multiparous cows. This agrees with a study showing that, within the same stage of lactation, parity affects lying bouts and lying bout duration in both tiestall- and freestall-housed cows (Vasseur et al., 2012). Another study following cows during the first 28 d after calving showed that loosely housed older cows lie down longer than younger cows kept in the same group (Steensels et al., 2012).

In dairy cattle, age and parity have been shown to be correlated with social dominance (e.g., Schein and Fohrman, 1955; Brantas, 1967). González et al. (2003) reported that first parity cows have more difficulties in coping with their environment under a competitive situation than multiparous cows. In our study, cows were moved to the lactation group as soon as they calved, as is typical of the management practice for this region. Moreover, cows were regrouped almost daily. Phillips and Rind (2001) compared the behavior of a group of late lactation cows before and after they were mixed. They found that comingled cows decreased grazing times and increased standing times; this effect was driven by the changes in primiparous cows in the days following regrouping. These authors also showed that multiparous cows increased their social rank on the days after mixing, suggesting that the grazing situation is a competitive one even though space availability is high. Phillips and Rind (2002) also reported that older cows are more likely to be the first to enter to the milking parlor. Although we did not monitor milking order, we expect that in our study primiparous cows were further down the milking order resulting in reduced lying times.

Lying Behavior and Postpartum Diseases

The increased lying times of cows diagnosed as sick agrees with the typical energy-conserving behaviors observed during illness, including rest and inactivity (Hart, 1988; Dantzer and Kelley, 2007). Such sickness behaviors are considered to be an adaptive response facilitating recovery (Dantzer and Kelley, 2007).

In the current study, we show a significant relationship between lying time and postpartum health status in primiparous cows, but not for multiparous cows, suggesting that first lactation cows cope less well with illness. Proudfoot et al. (2012) reviewed the literature on the effects social status on how animals respond to illness. Subordinate cows are more likely to engage in avoidance behavior in response to social confrontations after calving (Huzzey et al., 2007; Proudfoot et al., 2009). In our study, the first-lactation ill cows were

likely lower ranked within the group and thus may have avoided competitive interactions in part by spending more time lying down. Whether they were subordinate at the outset or became subordinate as a result of the disease is not known, but worthy of further research.

Postpartum diseases often occur in combination (Ingvarsen et al., 2003; Mulligan and Doherty, 2008). The increase in lying times and lying bout duration for ill cows was most apparent for cows with multiple disorders (retained placenta, severe metritis, mild metritis, or clinical mastitis); our study provides the first evidence that lying behavior is affected to a greater degree when cows are challenged with multiple disorders compared with a single disorder. Differences in the severity of the disease may also explain differences in the magnitude of the changes in behaviors after calving. For instance, cows that developed severe metritis spent less time feeding and consumed less feed compared with mildly metritic cows (Huzzey et al., 2007).

Our results confirm the value of lying behavior to detect common transition illnesses in dairy cows (dystocia, Proudfoot et al., 2009; subclinical hypocalcemia, Jawor et al., 2012) and are the first to show this relationship in grazing-based systems. The observed changes in the primiparous cows were relatively short-lived; 5 d after calving lying times were no longer different compared with the healthy cows. The short duration may have been due to effective treatment (5 of the 9 sick primiparous cows were treated for their illness; retained placenta $n = 4$ on d 2; severe metritis $n = 1$ on d 3) and to spontaneous cures. In addition to identifying ill animals, behavior can also be an early predictor of animals at risk for poor health (Weary et al., 2009). Unfortunately, we were unable to measure the lying behavior in the days before calving or before disease diagnoses. More research is required to evaluate lying behavior in the weeks before calving and how this relates to postpartum disease.

Lying Behavior and Lameness

The results of our study support the conclusions of others that lame cows differ in their lying behavior compared with nonlame cows whether at pasture (Hassall et al., 1993) or housed indoors (Galindo and Broom, 2002; Blackie et al., 2011). Severely lame cows lay down on average 1.7 h more than healthy, nonlame cows, which is similar to the increased lying times of 1.5 to 1.7 h reported for lame mid- to late-lactation cows at pasture (Hassall et al., 1993; Walker et al., 2008; Navarro et al., 2013) and the 1 to 2 h longer lying times in housed lame cows (Galindo and Broom, 2000; Chapinal et al., 2009; Ito et al., 2010).

In our study, clinically lame cows decreased the frequency of lying bouts and had longer lying bouts compared with healthy, nonlame cows. This agrees with other work for cows on pasture (Navarro et al., 2013) and indoors (Chapinal et al., 2009; Gomez and Cook, 2010; Ito et al., 2010). Chapinal et al. (2009) suggested that pain associated with lameness may reduce the willingness of a cow to stand up once she is lying down, but in our study severely lame cows tended to had more lying bouts than healthy cows. It is generally understood that lying surface may influence the processes of rising and lying down, especially for lame cows (reviewed by Cook and Nordlund, 2009). Pasture likely provides a better surface for performing these changes in posture compared with harder surfaces such as mattresses.

Our results failed to show a day $\times$ lameness status interaction during the study period. Calderon and Cook (2011) reported that cows that were diagnosed as lame during the prepartum period had no changes in gait scores up to 60 d after calving. Chapinal et al. (2009) found that cows diagnosed with claw ulcers in mid-lactation had a faster decline in lying time before calving and a faster increase after calving compared with cows that remained healthy, suggesting that the calving event is a major challenge for these cows.

Lameness prevalence is often underestimated by producers (Whay et al., 2003; Espejo et al., 2006). Ito et al. (2010) concluded that cows with high lying times or long lying bouts are more likely lame; thus, information on lying behavior could be used by farmers in some form of an alert system to identify cows that may benefit from a closer examination. We suggest that lying behavior data be used as a component of lameness detection on commercial pasture-based dairy systems.

CONCLUSIONS

Lying behavior differed between primiparous and multiparous cows in the first 3 wk after calving; primiparous cows had more lying bouts and spent less time lying down than multiparous cows. Lying behavior was also affected by illness; primiparous cows that developed more than one disorder after calving spent more time lying during the days following calving; multiparous lame cows spent more time lying down and had longer bouts compared with cows that were not lame.

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