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# Time budgets of lactating dairy cattle in commercial freestall herds

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## ABSTRACT

The aim of this study was to examine the time budgets of 205 lactating dairy cows housed in 16 freestall barns in Wisconsin and to determine the relationships between components of the time budget and herd- and cow-level fixed effects using mixed models. Using continuous video surveillance, time lying in the stall, time standing in the stall, time standing in the alleys (including drinking), time feeding, and time milking (time out of the pen for milking and transit) during a 24-h period were measured for each cow. In addition, the number of lying bouts and the mean duration of each lying bout per 24-h period were determined. Time milking varied between cows from 0.5 to 6.0 h/d, with a mean ± standard deviation of 2.7 ± 1.1 h/d. Time milking was influenced significantly by pen stocking density, and time milking negatively affected time feeding, time lying, and time in the alley, but not time standing in the stall. Locomotion score, either directly or through an interaction with stall base type (a rubber crumb-filled mattress, MAT, or sand bedding, SAND), influenced pen activity. Lame cows spent less time feeding, less time in the alleys, and more time standing in the stalls in MAT herds, but not in SAND herds. The effect of lameness on lying time is complex and dependent on the time available for rest and differences in resting behavior observed between cows in MAT and SAND herds. In MAT herds, rest was characterized by a larger number of lying bouts of shorter duration than in SAND herds (mean = 14.4; confidence interval, CI: 12.4 to 16.5 vs. mean = 10.2; CI: 8.2 to 12.2 bouts per d, and mean = 1.0; CI: 0.9 to 1.1 vs. mean = 1.3, CI: 1.2 to 1.4 h bout duration for MAT and SAND herds, respectively). Lameness was associated with an increase in time standing in the stall and a reduction in the mean number of lying bouts per day from 13.2 (CI: 12.3 to 14.1) bouts/d for nonlame cows to 10.9 (CI: 9.30 to 12.8) bouts/d for moderately lame cows, and an overall reduction in lying time in MAT herds compared with SAND herds (11.5; CI: 10.0 to 13.0 vs. 12.7; CI: 11.0 to 14.3 h/d, respectively). These results show that time out of the pen milking, stall base type, and lameness significantly affect time budgets of cows housed in freestall facilities.
**Key words:** dairy cow, lameness, time budget

## INTRODUCTION

In North America, the freestall barn has emerged as the dominant housing system, suitable for a variety of different climates (Cook and Nordlund, 2009). Here, the dairy cow is free to move about a "free" stall, where it may gain adequate rest; a water trough, where it may drink to satiate thirst; and a feed bunk, where it is free to graze a TMR to satisfy hunger for nutrients. In parlor-milked herds, the cow must leave the pen, typically 2 or 3 times per day, for a period usually not exceeding 1 h per milking. Increasing concern over the well-being of cattle in confinement housing (Garry, 2004) warrants a closer look at behavior in barns constructed over the last decade to understand more accurately the effect of the freestall environment on the cow.

The cow has little control over milking time in parlor facilities, because this is largely determined by management and parlor design. The time remaining in the pen must be voluntarily divided between activities such as eating, drinking, and rest, socializing in alleys, and standing in stalls. These activities make up the "time budget" for the dairy cow, and despite growing interest in the relative distribution of activities within the time budget (Grant, 2004), there is a dearth of peer-reviewed information on the subject.

Adequate daily rest appears essential for well-being (e.g., Munksgaard and Simonsen, 1996) and cows appear to be highly motivated to lie down for 12 to 13 h/d in confinement housing (Jensen et al., 2005; Munksgaard et al., 2005). Until recently, video capture was the only methodology used to track cow behavior in experimental pens (e.g., Tucker et al., 2003) and commercial facilities (e.g., Cook et al., 2004). Video capture and analysis, while considered the gold standard for behavioral monitoring, is time consuming, and tracking individual cows through large pens is technically challenging. Data loggers capable of automatically recording lying time and lying bout activity in commercial settings have been used recently to study cow behavior. Bewley et al. (2009) reported on lying data captured

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from 77 cows housed in 2 separate units and Ito et al. (2009) captured lying behavior from 2,033 cows housed on 43 commercial dairy farms in British Columbia. Using this new technology, a greater number of cows and herds can be monitored in larger pens of cattle for longer periods compared with video-capture techniques. Interest is emerging in the use of activity data to help predict health problems, such as lameness (Mazrier et al., 2006; Ito et al., 2010). However, the disadvantage of such studies is the lack of information that data loggers provide on the other components of the time budget, and the effect of, for example, milking time on the time available for rest. Only video-capture analysis currently provides this extra information, although in the future, lying time data loggers may be coupled with GPS or radar-based position analysis to determine the location of the cow on the farm (Schlecht et al., 2004; Gygax et al., 2007).

The aim of the present study was to use previously captured video data from lactating dairy cows in 16 commercial, freestall-housed dairy herds to examine the relationships between the components of the cow's time budget and the effect of external factors such as lameness and facility design. Such information may provide insight on elements of facility design and the management of dairy cows that may enhance production, health, and well-being.

## MATERIALS AND METHODS

### *Cow Selection and Data Collection*

Behavior data were captured using a consistent methodology described previously (Cook et al., 2004). Sony DCRTRV900 miniDV video cameras (Sony Corp., New York, NY) set to capture 1 s of video recording every 30 s were used. A total of 16 freestall barns were used for the analysis with cow data collected from 3 previously published studies (Cook et al., 2004, 2007, 2008). Complete time budgets for one entire day were available for 205 cows, with each herd contributing between 12 and 34 cows. Because heat stress is known to affect cow behavior (Cook et al., 2007; Marcillac-Embertson et al., 2009), only data collected below a mean ambient temperature of 18.3°C were included in this analysis. Cows from mixed-parity, high-production pens were selected randomly in 2 out of the 3 studies. Cow selection was stratified in the third study to include equal numbers of lame and nonlame cows in 4 herds (Cook et al., 2008). All time budgets included data collected continuously during a single 24-h period. No handling procedures were performed and no new additions were added to the pen for the period of filming. For each cow, the time lying (in the stall), feeding (with the cow's head observed over the feed bunk), standing in the alley (standing idle, walking, including time drinking near a water trough), standing in the stall (including perching half in and half out of the stall), and milking (time spent out of the pen in the parlor and for transfer to and from the pen) were recorded as a function of a 24-h day. In addition, the number of lying bouts and the mean lying bout duration (per 24-h period) were determined.

Ito et al. (2009) recorded lying activity for at least 44 cows in 38 herds over 5 d and determined that for the optimal determination of herd mean lying activity, 30 cows should be monitored for 3 d. However, they also showed that as few as 10 cows for as little as 1 d of monitoring could yield lying time predictions with greater than 60% accuracy for a behavior with the greatest variance between cows. The issues of management practices such as lock up time and cow movement in and out of pens under study were not taken into consideration for the implementation of these recommendations in a commercial setting, and it is likely that other behaviors (e.g., feeding) with less between-cow variance do not require the same monitoring standards suggested for predicting the lying behavior of the herd. Therefore, because the selected population was not completely randomized, and the sample size per herd was not considered ideal for the prediction of herd level averages, the focus of the current analysis will be on the relationships of components of the time budget with herd-level and cow-level fixed effects.

Mean (± SD) herd size was 250 ± 102 (range 70–400). Mean parity was 2.4 ± 0.7 for the 205 cows included, and mean DIM was 167 ± 95. Cows averaged 42.0 ± 10.5 kg of milk at the DHIA test before filming. Locomotion score (**LMS**) was collected on the day of filming by a single observer (N. Cook) as cows exited the parlor using a 4-point system described by Nordlund et al. (2004), with 104, 66, and 35 cows scoring LMS 1 (nonlame), 2 (slightly lame), and 3 (moderately lame), respectively. No cows were filmed with a LMS of 4 (severely lame).

The herds were milked twice ($n = 9$) or 3 times ($n = 7$) daily. Ten herds had stall layouts with 2-row pens and 6 herds had 3-row pens. The stocking density across herds ranged from 0.83 to 1.26 cows per stall (mean = 1.05 ± 0.10) in pens that ranged in size from 50 to 110 cows. Stall base used for each herd was assigned to 2 categories: **MAT** was used for rubber crumb-filled mattresses bedded with a small amount of organic bedding (8 herds) and **SAND** was used for both deep sand stalls and stalls with at least 5 cm of sand over a mattress base (8 herds). Details of stall design and dimensions have been discussed previously (Cook et al., 2004, 2008).

**Table 1.** Mean, median, SD, minimum, and maximum and upper and lower quartile (Q25 and Q75) cut-points for the component activities of the daily time budget for 205 cows housed in 16 freestall herds

| Activity | Mean | Median | SD | Minimum | Q25 | Q75 | Maximum |
|---|---|---|---|---|---|---|---|
| Time milking (h/d) | 2.7 | 2.5 | 1.1 | 0.5 | 1.8 | 3.5 | 6.0 |
| Time feeding (h/d) | 4.3 | 4.3 | 1.1 | 1.1 | 3.5 | 5.0 | 8.1 |
| Time in alley incl. drinking (h/d) | 2.5 | 2.1 | 1.5 | 0.4 | 1.5 | 3.1 | 7.5 |
| Time standing in stall (h/d) | 2.7 | 2.0 | 2.1 | 0.3 | 1.2 | 3.6 | 10.9 |
| Time lying (h/d) | 11.9 | 12.1 | 2.4 | 3.9 | 10.6 | 13.5 | 17.6 |
| Lying bouts (n) | 12.9 | 11.0 | 6.6 | 3.0 | 9.0 | 15.0 | 35.0 |
| Lying bout duration (h) | 1.2 | 1.1 | 0.4 | 0.4 | 0.9 | 1.4 | 2.9 |

### *Statistical Analysis*

Data were analyzed using cow as the unit of observation. Descriptive summaries, including correlation matrices for the different pen activities, were obtained with the statistical package R (v. 2.7, http://www.R-project.org; R Development Core Team, 2009), using a variety of package features. Transformations were used to meet the assumptions of equal variance and normality of the residuals, evaluated by examining the plots of residuals against predicted values. For time standing in the stall, time in the alley, number of lying bouts, and mean lying bout duration, log-transformations were used. For time lying, the 1.5 power was used, whereas for time milking and DIM, the square root was chosen. The LME function in the NLME package (Pinheiro et al., 2009) was used to perform the final analysis of covariance for each component of the time budget, with study period and farm (nested in study period) as random effects over the intercept using a manual stepwise backward elimination to choose statistically significant covariates at the 95% confidence level. Covariates were left in the final models if they were part of a significant interaction term. The goodness of fit of the models was monitored using Akaike's information criterion. Herd-level fixed effects used in the models included stall base type (SAND or MAT), number of rows of stalls in the pen (2-row or 3-row), milking frequency (2 or 3 times/d), and stocking density (cows per stall) in the pen on the day of filming. Cow-level fixed effects included parity (1, 2, or ≥3), LMS (1–3), DIM (days postpartum), and last DHIA-recorded milk yield (kg/d). All fixed effects that were not numeric variables were included as categorical variables (factors). Estimates and standard errors, degrees of freedom, and $P$-values for fixed effects calculated with the likelihood ratio test were used to report the output of the final models. Where prediction means from back-transformed variables are quoted, they are reported with 95% confidence intervals.

Differences in time milking are largely driven by facility design and management differences between herds, and because the Pearson correlation coefficients between time milking for each cow and their other pen activities were found to be <0.24, we concluded that the variable could be used in the models for other behaviors to correct for the daily time remaining in the pen available for other activities. Time milking was therefore included in the models for time lying, time standing in the stall, time feeding, and time in the alley as a predictor variable.

## RESULTS AND DISCUSSION

### *Time Milking*

For all cows, mean (± SD) time spent milking was 2.7 ± 1.1 h/d, with a range of 0.5 to 6 h/d for herds milked twice a day and 1.2 to 5.7 h/d for herds milked 3 times a day (Table 1). The final model for time milking was significant for stocking density (regression estimate 0.011, SE 0.004, $P$ = 0.003) and was independent of milking frequency ($P$ = 0.3) and LMS ($P$ = 0.9).

When farmers add cows to a fixed-size pen without changing parlor size or throughput, overstocking may increase time spent milking, which reduces the time available in the pen for other essential activities. In subsequent models, increased time milking reduced time feeding, time spent in the alley, and time lying. Thus, if we are to design and manage facilities to optimize the time available for these other essential pen activities, thought must be given to minimizing time away from the pen through correct parlor sizing, optimizing throughput, and minimizing the distance traveled to and from the milking center. Overstocking has also been shown to have a direct effect on lying time through competition (Fregonesi et al., 2007).

Although milking frequency did not significantly affect time milking in the current study, in any given herd, a switch from 2- to 3-times-a-day milking may be expected to increase the mean time spent milking. Milking order is not random, because of dominance and other factors (Rathore, 1982; Cook and Nordlund, 2009), and individual cows spent up to 6 h/d being milked in this study. Herd owners therefore need to be aware of the effect of extending time spent milking on the cow's time budget before making management decisions that may negatively affect the cow.

**Table 2.** Outcome of the mixed model for time feeding including regression estimates, SE, likelihood ratio (LR), degrees of freedom, and *P*-values for overall significance of fixed effects

| Variable | Estimate | SE | LR | df | *P*-value |
|---|---|---|---|---|---|
| Intercept | 3.15 | 0.41 | | | |
| Time milking | −0.16 | 0.08 | 4.25 | 1 | 0.039 |
| LMS[1] | | | | | |
| 1 | 0.39 | 0.28 | 5.41 | 2 | 0.066 |
| 2 | 0.15 | 0.28 | | | |
| 3 | Ref.[2] | | | | |
| Parity | | | | | |
| 1 | 0.49 | 0.20 | 9.11 | 2 | 0.010 |
| 2 | 0.15 | 0.21 | | | |
| ≥3 | Ref. | | | | |
| Milk yield | 0.01 | 0.01 | 15.40 | 1 | <0.001 |

[1]LMS = locomotion score, where LMS 1 = nonlame, LMS 2 = slightly lame, and LMS 3 = moderately lame.

[2]Reference class.

Recently, Main et al. (2010) demonstrated a significantly greater prevalence of lame cows in the last third of the milking order, and Espejo and Endres (2007) found that longer time spent milking was significantly associated with increased lameness prevalence. However, LMS was not a significant factor associated with milking time in the current study, perhaps because severely lame cows were not included in the population. This finding does suggest, however, that mildly and moderately lame cows are distributed throughout the entire milking group. Main et al. (2010) recently confirmed that 34% of the cows in the first third of the milking order on 67 farms were lame. Surveillance for lame cows for treatment should therefore incorporate the entire group, not just the cows at the rear of the holding area.

### Time Feeding

Of all of the components of the time budget, time feeding showed the least variance between cows with mean (± SD) time feeding of 4.3 ± 1.1 h/d (Table 1). Factors significant in the model for time feeding are shown in Table 2 and included time milking, parity, milk yield, and LMS. First-lactation heifers ate for a mean (± SE) of 4.48 ± 0.21 h/d, compared with 4.55 ± 0.09 and 4.06 ± 0.11 h/d for second and third or greater lactation cows respectively. Differences between parity 1 compared with parity ≥ 3 were significant at $P < 0.05$. Lameness affected time feeding, with the greatest feeding times observed in nonlame cows. The contrasts between LMS 1 (4.50 ± 0.09 h/d) and both LMS 2 (4.15 ± 0.14 h/d) and LMS 3 (3.79 ± 0.18 h/d) were significant at $P < 0.05$.

Greater time milking was associated with less time feeding, suggesting that reducing time in the pen has the potential to alter feeding behavior and production as milk yield was positively associated with time feeding. The parity effect is consistent with Azizi et al. (2010), who found that primiparous cows had a lower feeding rate, took more meals of smaller size, and spent more time feeding than older cows. González et al. (2008) noted a decline in feeding time in freestall-housed dairy cattle with locomotion disorders that was associated with a decrease in intake, and the effect may be of particular importance where bunk space is limited. The influence of restricted feed space on the feeding activity of individuals within groups has been well documented (DeVries et al., 2004).

### Time Standing in the Alley, Including Drinking

Mean (± SD) time in the alley for all cows was 2.5 ± 1.5 h/d (Table 1). Factors significant in the model for time in the alley are shown in Table 3 and include time milking and LMS. Mean (± 95% CI) time in the alley for LMS 1, 2, and 3 cows was 2.37 (2.27 to 2.48), 1.94 (1.83 to 2.06), and 1.82 (1.65 to 2.00) h/d, respectively, with the contrasts between LMS 1 cows and both LMS 2 and LMS 3 cows significantly different at $P < 0.05$.

The physical act of drinking appears to take approximately 5 to 7 min/d (Huzzey et al., 2005; Cardot et al., 2008); the majority of time spent in the alley in a freestall pen appears to be voluntary for transfer between the resting and feeding area and socializing. Time in the alley was reduced with increasing time spent milking under thermoneutral conditions in the current study, but under conditions of heat stress, cows may spend more time standing in alleys near fans attempting to cool off (Cook et al., 2007).

As with time spent feeding, lameness emerged as a significant factor influencing time in the alley. The reduction in time in the alley observed in lame cows is possibly due to the avoidance of aggressive encounters with dominant cows (Galindo et al., 2000; Proudfoot

**Table 3.** Outcome of the mixed model for time standing in the alley including drinking, including regression estimates, SE, likelihood ratio (LR), degrees of freedom, and *P*-values for overall significance of fixed effects

| Variable | Estimate | SE | LR | df | *P*-value |
|---|---|---|---|---|---|
| Intercept | 1.01 | 0.25 | | | |
| Time milking | −0.34 | 0.14 | 7.03 | 1 | 0.008 |
| LMS[1] | | | | | |
| 1 | 0.39 | 0.11 | 12.69 | 2 | 0.001 |
| 2 | 0.15 | 0.12 | | | |
| 3 | Ref.[2] | | | | |

[1]LMS = locomotion score, where LMS 1 = nonlame, LMS 2 = slightly lame, and LMS 3 = moderately lame.

[2]Reference class.

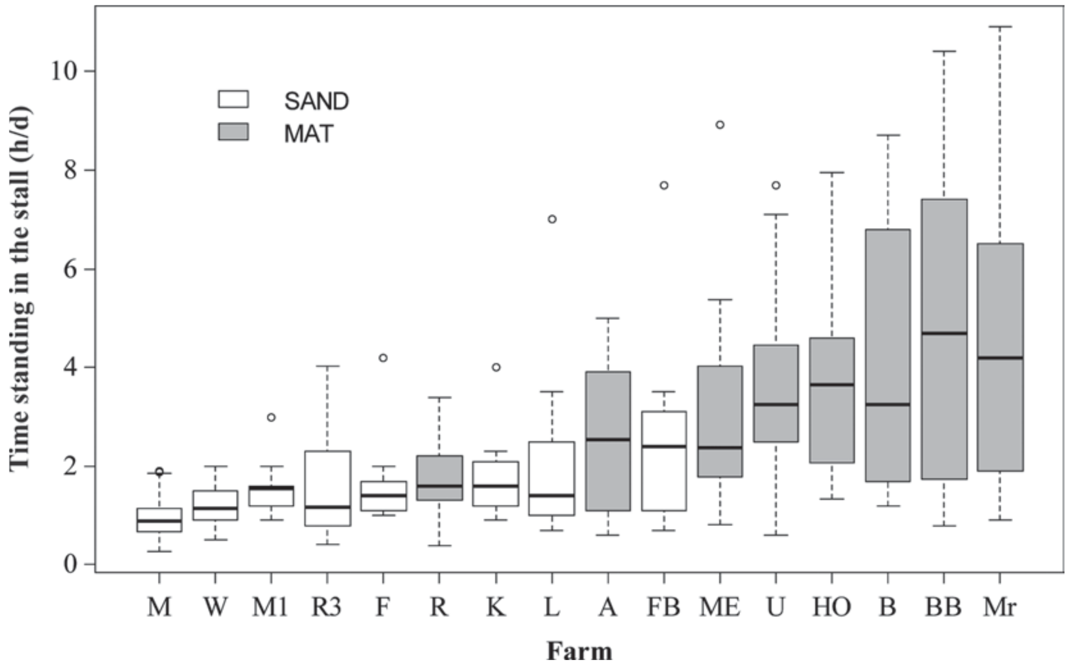


**Figure 1.** Boxplot of time standing in the stall for 16 herds with between 12 and 34 cows per herd by stall base type (MAT or SAND). Stall base used for each herd was assigned to 2 categories: MAT was used for rubber crumb-filled mattresses bedded with a small amount of organic bedding (8 herds), and SAND was used for both deep sand stalls and stalls with at least 5 cm of sand over a mattress base (8 herds). The circles indicate outliers (values greater than 1.5 times the interquartile range).

et al., 2009), or it may be a product of a voluntary or involuntary shift in standing location in the pen from the alley to the stalls (Tucker et al., 2003; Cook et al., 2004). It also is possibly due to greater time spent lying, which has been observed in lame cows in some studies (e.g., Ito et al., 2010). Some evidence suggests that standing time on concrete is significantly associated with lameness (reviewed in Cook and Nordlund, 2009), but the causative link has yet to be determined, and the findings of this study suggest that more work is needed to understand completely the association.

### *Time Spent Standing in the Stall*

Mean ($\pm$ SE) time spent standing in the stall for all cows was $2.7 \pm 2.1$ h/d (Table 1). Although some herds showed very little variance between cows, it was much greater in others, notably in the MAT herds with the 6 longest mean times standing in the stall (Figure 1). From Table 4, the model for time standing in the stall had significant effects on stocking density, parity, and interaction between stall base and LMS (Figure 2) . For all cows, time standing in the stall was significantly greater in MAT cows (2.69 h/d; 1.50–3.88) compared with SAND cows, (1.46 h/d; 0.24–2.67). Each LMS category was significantly different between SAND and MAT herds, and within MAT herds, LMS 2 and 3 were significantly different from LMS 1 cows ($P < 0.05$). Notably, time standing in the stall was independent of time spent in the pen, as milking time was not significant.

The negative relationship with stocking density suggests that cows stand less in the stall when access is limited, confirming that stall occupancy is a valued resource (Fregonesi et al., 2007). The significantly greater time spent standing in the stall observed in MAT cows compared with SAND cows may be due to a voluntary choice made by the cow preferring to stand on a mattress rather than on concrete in an alley (Galindo et al., 2000; Tucker et al., 2003), or be involuntary, due to difficulty rising and lying in MAT stalls (Cook and Nordlund, 2009). Time standing in the stall increased with both parity and lameness. The reduced time standing in the stall observed in primiparous cows may relate to increased observed time spent feeding, competition within the time budget, the effect of lameness observed in older cows, or some combination of these factors. The relationship between time standing in the stall and lameness, shown graphically in Figure 2, is believed to favor the argument that the increased standing activity observed in stalls in MAT herds, but not in SAND herds, is likely more involuntary (resulting from lameness) than voluntary (resulting from free choice and

**Table 4.** Outcome of the mixed model for time standing in the stall including regression estimates, SE, likelihood ratio (LR), degrees of freedom, and *P*-values for overall significance of fixed effects

| Variable | Estimate | SE | LR | df | *P*-value |
|---|---|---|---|---|---|
| Intercept | 2.47 | 0.56 | | | |
| Stocking density | −0.02 | 0.01 | 10.72 | 1 | <0.001 |
| Parity | | | | | |
| 1 | −0.23 | 0.14 | 9.65 | 2 | <0.001 |
| 2 | −0.18 | 0.09 | | | |
| ≥3 | Ref.[1] | | | | |
| LMS[2] | | | | | |
| 1 | −0.22 | 0.21 | 35.22 | 2 | <0.001 |
| 2 | −0.08 | 0.22 | | | |
| 3 | Ref. | | | | |
| Stall base type[3] | | | | | |
| MAT | 0.95 | 0.23 | 29.66 | 1 | <0.001 |
| SAND | Ref. | | | | |
| Stall base type × LMS[4] | | | 10.08 | 2 | 0.006 |
| MAT × LMS 1 | −0.55 | 0.25 | | | |
| MAT × LMS 2 | 0.04 | 0.26 | | | |
| MAT × LMS 3 | Ref. | | | | |

[1]Reference class.

[2]LMS = locomotion score, where LMS 1 = nonlame, LMS 2 = slightly lame, and LMS 3 = moderately lame.

[3]Stall base used for each herd was assigned to 2 categories: MAT was used for rubber crumb-filled mattresses bedded with a small amount of organic bedding (8 herds), and SAND was used for both deep sand stalls and stalls with at least 5 cm of sand over a mattress base (8 herds).

[4]Refer to Figure 2 for interaction between stall base type and LMS.

preference). Cook and Nordlund (2009) hypothesized that the cushion, traction, and support provided by sand bedding facilitates the rising and lying movements of lame cows, compared with the firm flat surface provided by a mattress, which creates difficulties for lame cows trying to maintain their normal resting behavior.

### Resting Behavior

The mean (± SD) time lying was 11.9 ± 2.4 h/d, with a range of 3.9 to 17.6 h/d (Table 1). This resting behavior was achieved with a mean number of lying bouts (± SD) of 12.9 ± 6.6 and mean lying bout duration (± SD) of 1.2 ± 0.4 h. Factors significant in the model for time spent lying are shown in Table 5 and include time milking, DIM, and an interaction between the effect of stall base type and LMS (Figure 3). Overall, cows in MAT herds spent significantly less time lying than did cows in SAND herds [11.50 (10.00 to 13.00) vs. 12.66 (11.03 to 14.29) h/d respectively]. Within MAT herds, mean time lying for LMS 3 (10.83 h/d; 8.08 to 13.27) cows was less than for LMS 1 cows (12.07 h/d; 10.53 to 13.52) at $P < 0.05$, whereas no significant difference was observed between LMS categories in SAND herds. Results for the models for number of lying bouts and lying bout duration are given in Table 6. Taken together, resting behavior in cows in MAT herds was categorized by less time spent lying comprising a greater number of shorter duration bouts compared with cows in SAND herds. Lameness was associated with a reduction in number of lying bouts, but no significant change in bout duration.

The resting behavior observed in the current study compares with data from other commercial herds, such as Ito et al. (2009), where cows lay down for 11.0 ± 2.1 h/d, in 9 ± 3 bouts/d, with a mean bout duration of 1.5 ± 0.5 h, and from Bewley et al. (2009), where mean lying time was 10.5 ± 2.1 h/d, in 11.0 ± 3.9 bouts. These data are likely influenced by the proportion of lame cows included in each study. Several studies have found that lame cows lie down longer than nonlame cows in freestalls (Singh et al., 1993; Chapinal et al., 2009; Ito et al., 2010) in apparent contrast to the findings of this study. However, it is clear that the relationship between lameness and time lying is complex and may vary for different types of management (e.g., different time spent milking) and facility design (e.g., different stall base types). For example, Ito et al. (2010) found that severely lame cows in deep-bedded stalls in 11 herds lie down longer than nonlame cows, whereas in mattress herds, no difference in lying time was observed. These data relate to herds with an average size of 177 cows, predominantly milked twice per day. Figure 3 shows the complex interaction between stall base type, LMS, and time milking and its effect on lying time found in the current study. From the model, it shows that lying time for lame cows in SAND herds was indeed longer than for nonlame cows, which is consistent with the findings of Ito et al. (2010). However, it also highlights the interaction with time milking and demonstrates the

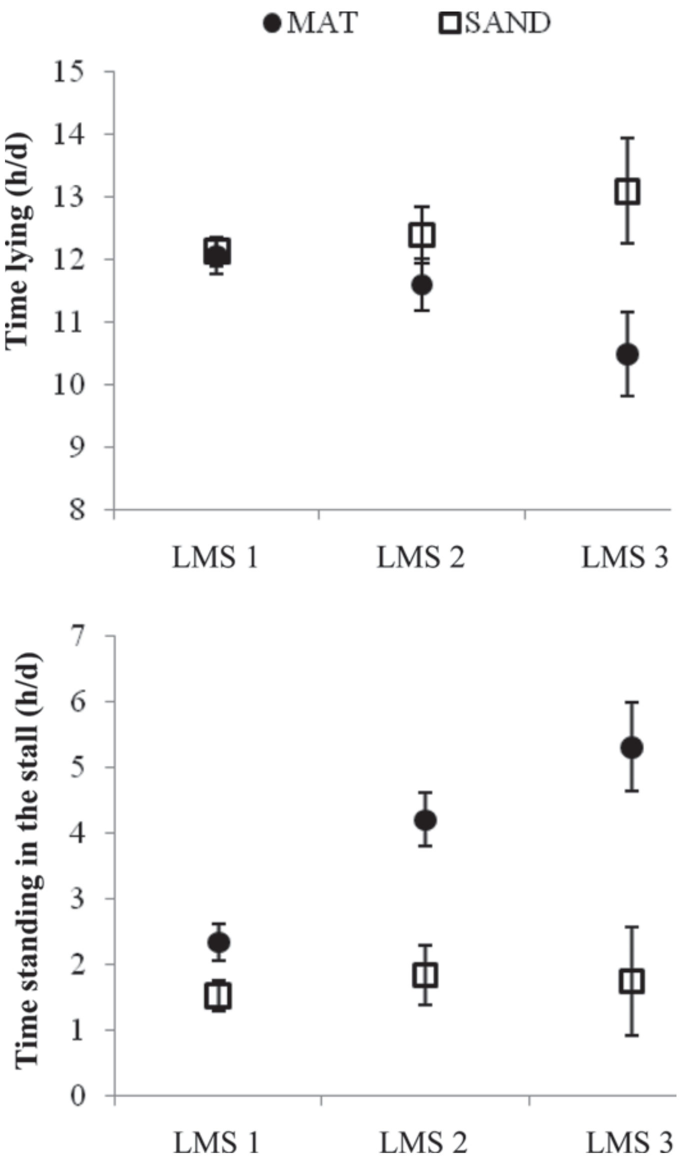


**Figure 2.** Interaction plot between locomotion score (where LMS 1 = nonlame, LMS 2 = slightly lame, and LMS 3 = moderately lame) and stall base type (MAT or SAND) for time standing in the stall (h/d) and time lying (h/d) with SEM bars. Stall base used for each herd was assigned to 2 categories: MAT was used for rubber crumb-filled mattresses bedded with a small amount of organic bedding (8 herds), and SAND was used for both deep sand stalls and stalls with at least 5 cm of sand over a mattress base (8 herds).

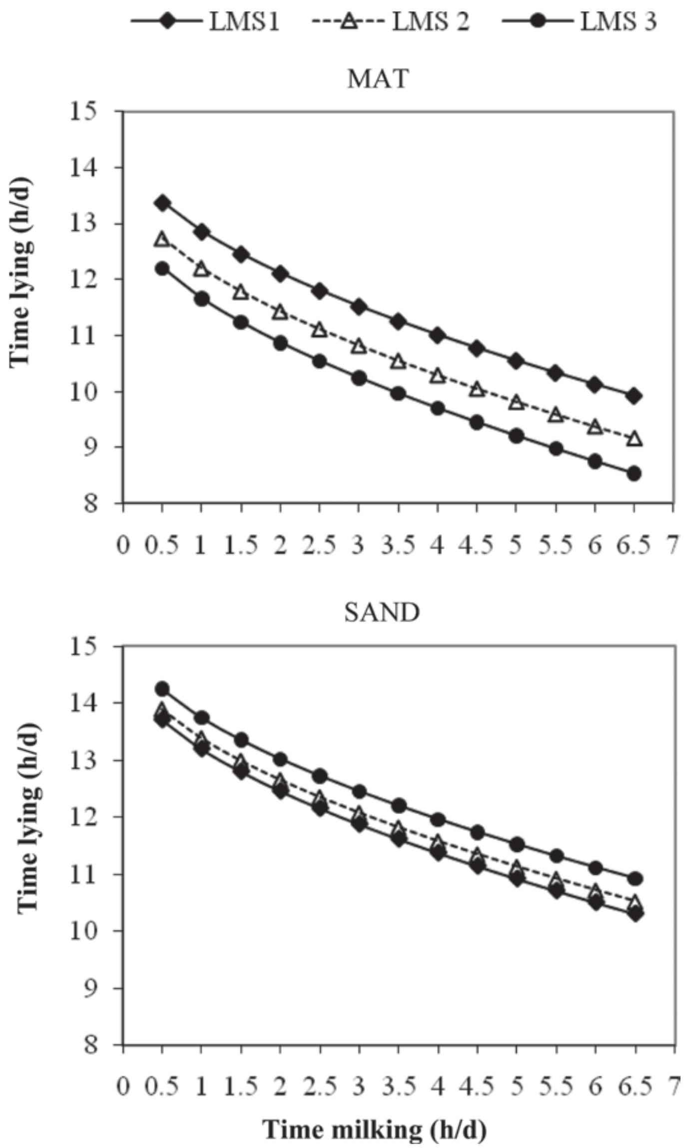


**Figure 3.** Predicted time lying values (h/d) for locomotion score (LMS) 1, 2, and 3 (where LMS 1 = nonlame, LMS 2 = slightly lame, and LMS 3 = moderately lame cows) depending on time milking and type of stall base (MAT or SAND). Stall base used for each herd was assigned to 2 categories: MAT was used for rubber crumb-filled mattresses bedded with a small amount of organic bedding (8 herds), and SAND was used for both deep sand stalls and stalls with at least 5 cm of sand over a mattress base (8 herds). Days in milk was standardized to 100 d.

dramatic reduction in time lying observed in lame cows housed in MAT herds, particularly when time milking is prolonged. We have demonstrated significant reductions in time feeding and time standing in the alley associated with lameness in the current data; therefore, the reduction in observed lying time in lame cows in MAT herds appears to be related to increased time standing in the stall.

In an environment characterized by resting behavior that is predicated by a greater number of bouts of short duration, such as a herd with mattress stalls, time lying is likely to be more influenced by lameness than it would be for cows with sand stalls; such cows take fewer longer-duration bouts. Whereas Chapinal et al. (2009) found that cows suffering from sole ulcers had greater lying times and longer bouts, the cows in that

**Table 5.** Outcome of the mixed model for time lying including regression estimates, likelihood ratio (LR), SE, degrees of freedom, and *P*-values for overall significance of fixed effects

| Variable | Estimate | SE | LR | df | *P*-value |
|---|---|---|---|---|---|
| Intercept | 53.79 | 6.51 | | | |
| Time milking | −9.58 | 2.86 | 16.17 | 1 | 0.001 |
| DIM | 0.67 | 0.21 | 10.01 | 1 | 0.001 |
| LMS[1] | | | | | |
| 1 | −2.99 | 3.90 | 6.93 | 2 | 0.139 |
| 2 | −1.97 | 3.99 | | | |
| 3 | Ref.[2] | | | | |
| Stall base type[3] | | | | | |
| MAT | −11.15 | 4.83 | 7.96 | 1 | 0.046 |
| SAND | Ref. | | | | |
| Stall base type × LMS[4] | | | 4.50 | 2 | 0.105 |
| MAT × LMS 1 | 9.29 | 4.75 | | | |
| MAT × LMS 2 | 4.79 | 4.95 | | | |
| MAT × LMS 3 | Ref. | | | | |

[1]LMS = locomotion score, where LMS 1 = nonlame, LMS 2 = slightly lame, and LMS 3 = moderately lame.

[2]Reference class.

[3]Stall base used for each herd was assigned to 2 categories: MAT was used for rubber crumb-filled mattresses bedded with a small amount of organic bedding (8 herds), and SAND was used for both deep sand stalls and stalls with at least 5 cm of sand over a mattress base (8 herds).

[4]Refer to Figure 2 for interaction between stall base type and LMS.

study were housed on sand-bedded freestalls, which tend to promote that type of resting behavior, perhaps due to the greater cushion and support provided by sand. In MAT herds in the current study, lame cows stood for longer in the stall, which was associated with reduced lying time. However, it is possible that with reduced time out of the pen milking (e.g., in smaller herds milked twice a day), a reduction in lying time in lame cows may not be observed (e.g., Ito et al., 2010). Therefore, to understand the effect of lameness on resting behavior, it is important to take into account time milking and changes in stall standing activity.

If the cow must interact with the stall surface during both rising and lying movements, the effect on time lying may be bidirectional. Lame cows may lie longer because rising is difficult, or they may stand longer and lie down less because lying down is difficult. In this data set, this complex issue was explored by examining the distribution of cows by LMS and stall base type, and by determining whether the cows lay down for a long or short period. Cut-points were developed for the upper and lower quartiles of time lying to include 49 short-lying-time (<10.6 h/d) and 51 long-lying-time (>13.5 h/d) cows (Table 1). In MAT herds, 51% (17/33) of the nonlame cows had long lying times compared with 45% (5/11) in SAND herds. However, only 35% (11/31) of the lame cows (LMS 2 and 3) in MAT herds had long lying times, compared with 72% (18/25 cows) of the lame cows in SAND herds. Thus, if we are to believe that rest is beneficial for lame cows (Cook and Nordlund, 2009), it appears that more lame cows benefit in SAND herds than they do in MAT herds, and this is a

**Table 6.** Prediction means (95% CI) for outcomes of the mixed models for the number of lying bouts per day and lying bout duration and *P*-values for Type III sum of squares

| | Lying bouts (no./d) | | | Lying bout duration (h) | | |
|---|---|---|---|---|---|---|
| Variable | Mean prediction | 95% CI | *P*-value | Mean prediction | 95% CI | *P*-value |
| Stall base type[1] | | | | | | |
| MAT | 14.44 | 12.42 to 16.45 | 0.049 | 1.02 | 0.94 to 1.10 | 0.014 |
| SAND | 10.22 | 8.20 to 12.24 | | 1.30 | 1.20 to 1.40 | |
| LMS[2] | | | | | | |
| 1 | 13.23 | 12.31 to 14.15 | 0.051 | | | NS |
| 2 | 12.85 | 11.87 to 13.82 | | | | |
| 3 | 10.91 | 9.02 to 12.81 | | | | |

[1]Stall base used for each herd was assigned to 2 categories: MAT was used for rubber crumb-filled mattresses bedded with a small amount of organic bedding (8 herds), and SAND was used for both deep sand stalls and stalls with at least 5 cm of sand over a mattress base (8 herds).

[2]LMS = locomotion score, where LMS 1 = nonlame, LMS 2 = slightly lame, and LMS 3 = moderately lame.

potential reason for the significant difference in lameness prevalence observed between the 2 groups (Cook et al., 2004; Espejo et al., 2006).

## CONCLUSIONS

Lameness had a significant effect on cow time budgets. In the current study, lame cows spent less time feeding, less time standing in the alley, and—in MAT herds only—greater time standing in the stall. Lame cows had fewer lying bouts each day, and in MAT herds, moderately lame cows had reduced lying time compared with nonlame cows, an effect not observed in SAND herds. Stall base type influenced resting behavior. In MAT herds, rest was characterized by a greater number of shorter duration bouts compared with SAND herds. Thus, if lame cows have greater difficulty rising and lying down resulting from a painful lesion, behavior is likely more affected in MAT herds, where cows change position more frequently. Indeed, the effect of lameness on lying time may be bidirectional: some lame cows may find it difficult to lie down and thus stand in the stall for longer, whereas others may find it difficult to stand and thus lie down for longer. A greater proportion of lame cows had longer lying times in SAND herds than in MAT herds, and if rest is important for recuperation from lameness, more cows appeared to benefit in this environment. This behavioral difference may contribute to the lower prevalence of lameness observed in SAND herds. To understand the full effect of lameness on cow behavior, factors such as stall base type and time spent performing other activities must be considered.

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