Using precision technology to detect the onset of digital dermatitis in dairy cows

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Abstract

Digital dermatitis (DD) is a multifactorial infectious disease of the hoof that causes inflammation and painful lesions primarily located digitally and on the coronary band. Changes in cow behaviors are associated with lameness, yet behavioral data related to the onset of DD is limited. The aim of this study was to evaluate behavioral differences between cows with healthy feet and cows with DD, as well as changes in behavior associated with the onset of DD. Lactating Holstein cows (n = 42) were observed in the parlor daily June-July 2020, for visual hoof evaluations. Behavior data was collected for 1 wk prior to the onset of DD using CowManager® activity monitoring ear tags that recorded activity, eating, and ruminating behaviors, and ear temperature. Data were analyzed using mixed model ANOVA and linear regression in SAS. An interaction was detected between day relevant to diagnosis of DD (Pre-diagnosis, 0/Day of diagnosis, Post-diagnosis) and hoof health (healthy or DD) for active ($P < 0.0001$) and eating ($P < 0.0001$) behaviors. Cows with DD tended ($P = 0.08$) to spend 0.07 ± 0.01 h/d less time active prior to a DD diagnosis. A three-way interaction was observed among day relative to the onset of DD, hoof health, and cow lactation number for inactivity ($P = 0.03$) and high activity ($P = 0.05$). Prior to the onset of DD, cows spent 0.03 ± 0.01 h/d less time highly active ($P = 0.04$). Ear temperature was associated with day relative to the onset of DD and hoof health ($P < 0.0001$). Prior to the onset of DD, average ear temperature increased by 0.16 ± 0.03°C ($P < 0.0001$). In conclusion, cows that developed DD altered their behaviors prior to diagnosis. Understanding the progression of this disease could promote early treatment and better prognosis.

Keywords: Cow behavior, digital dermatitis, ear tag sensors.

Introduction

Digital dermatitis (DD) is a multifactorial infectious disease that causes inflammation and is classified by painful lesions primarily located digitally and on the coronary band of the hoof. DD is typically accompanied by lameness, due to the lesions, along with other infectious and non-infectious diseases including: foot rot; sole ulcers; sole hemorrhages; and white line disease. Digital Dermatitis severity can be assessed on a scale of M0 through M4 stages depending on the size, color, and pain of the lesion (Döpfer *et al.*, 1997). The accompanying symptom of digital dermatitis, lameness, negatively impacts animal welfare in dairy cattle and leads to economic loss in the dairy industry (USD$1.1 billion; Zinicola *et al.*, 2015). DD affects 25% of dairy farms and has led to a large economic loss partially due to a decrease in milk production (0.6 kg/day; Relun *et al.*, 2013).

Literature surrounding digital dermatitis remains limited and has been encompassed under the condition lameness. Lameness impacts changes in animal behavior such as lying time which in turn can cause decreases in the amount of time spent eating and feed intake, leading to reductions in milk production (Yunta, 2012; Norring *et al.*, 2014; Argaez-Rodriguez, 1998). Although behavioral data such as these have been studied in lame cows, behavioral data related to the detection of digital dermatitis in cows remains very limited. Behavioral monitoring systems range from neck collars to detect head movements and assess eating and ruminating time, while ankle bracelets can be used to detect pedometry and assess activity time. CowManager® (CowManager B.V., Harmelen, Netherlands) is a common behavioral monitoring system on dairy farms. CowManager® receives its data using ear tags that record daily behaviors such as rumination, eating time, ear temperature, and activity time. These systems have been used as reliable methods to compare an individual to the herd population and detect lameness as well as other diseases in cattle.

Currently, the most common method of DD detection is observational through changes in gait assessed through locomotion scoring, and physical examination of the hoof (Harris-Bridge *et al.*, 2018; Mohamadnia and Khaghani, 2013). Studies using precision technology, such as behavioral monitoring systems, to monitor DD has primarily focused on detection (the mere presence of DD), yet little has been done to evaluate the onset of DD using changes in animal behavior. Due to the progression of the disease, it is not usually noticed until it causes pain that results in cattle putting minimal pressure on the hoof, leading to lameness. The inability to detect the onset of DD impacts animal well-being and is a vital area of research that should be investigated to promote early treatment and a better prognosis.

Materials and methods

All procedures used in this study were approved by the WSU IACUC (ASAF# 6770). The study was conducted from June 2020 to July 2020 at the Washington State University Knott Dairy Center (KDC) in Pullman, Washington, USA. The facility houses 180 lactating Holstein cows in free-stall barns. As a prevention method for DD, an acidified copper sulfate and zinc footbath solution was placed at the exit of the milking parlor. The footbath solution was replaced twice a week through recommendation of a hoof specialist.

Visual assessment of hoof health

The lead researcher for this study was trained by a hoof specialist to evaluate digital dermatitis (DD) lesions. All hoof assessments were conducted during morning milkings in the milking parlor from 0900 h – 1300 h. Lesion status was categorized as active (red and painful with hair on lesion) or degressing (no hair or little hair that lies flat, no pain, and scabbing on lesion). Lesion size was categorized as small (< 0.635 cm), medium (0.635 cm <x< 3.81 cm), and large (> 3.81 cm) by diameter. Cattle were enrolled into the study if they were healthy (no hoof lesions) for at least 7 days before the first observation of an active lesion. Each cow with DD was matched with a healthy counterpart that had the same lactation number, reproduction status, and similar days in milk. The same researcher recorded DD status and size daily until the end of the study.

Cow behavior evaluation

Each lactating cow at the Knott Dairy Center wore a CowManager® (CowManager B.V., Harmelen, Netherlands) ear tag that continuously recorded each cow's behavior 24 hours every day throughout the study. The behaviors of interest in this study were activity, eating, and lying. Once a cow was enrolled into the study, the behavioral data was matched with a healthy cohort according to lactation number, days in milk (or lactation period), and reproductive status. All behavioral data were calculated as the proportion of time each cow spent exhibiting each behavior every day.

Statistical analysis

Prior to statistical analysis, the dependent variables for behavior data were tested for normality using the UNIVARIATE procedure of SAS (SAS 9.4, SAS Institute, Cary, NC, USA) and no transformation of the data was required.

The analyses were performed using a mixed model ANOVA in SAS (PROC MIXED; SAS 9.4, SAS Institute, Cary, NC, USA) for dependent variables: non-active; active; high active; eating; ruminating; and ear temperature. Day in relation to the detection of DD was divided between pre-DD, day 0, and post-DD. Statistical significance was classified as P d" 0.05. Cows that developed digital dermatitis during the study (n = 21) were compared to healthy cows (n = 21).

Cows enrolled into the onset cohort were required to meet the following criteria: > 7 days healthy and > 2 consecutive days of DD lesion present. Statistical analysis for the onset of DD dataset (n = 18) was performed using a regression model in SAS (SAS 9.4, SAS Institute, Cary, NC, USA) for dependent variables: non-active, active, high active, eating, ruminating, and ear temperature. The independent variables used for this model included day in relation to detection of DD. Day 0 was relative to first day of diagnosis and days prior followed a -1, -2, -3, -4….. day sequence until the first day of data collection.

Results

Healthy cows versus cows with DD

Non-active behavior

A three-way interaction was detected when testing non-active behavior between hoof health (DD or healthy), lactation number, and day relative to diagnosis of DD (P = 0.03; Figure 1).

When comparing cows with DD and healthy cows within day 0 of diagnosis, first lactation cows with DD spent 1.76 ± 0.74 h/day less time non-active than healthy cows within their third or higher lactation (P = 0.02). This was also seen pre-diagnosis of DD where healthy cows with three or more lactations exhibited 1.64 ± 0.69 h/day more non-active behavior compared to first lactation cows with DD (P = 0.02).

Healthy cows demonstrated changes in non-active behavior within stages of lactation. As healthy cows increased in number of lactations, non-active time increased (Figure 2). This pattern was observed in all three stages relevant to day of diagnosis (pre, 0, post). Most significantly, when comparing healthy cows at the beginning of the study to the cows closer to the end of the study, those with lower lactations (Lact 1) had lower non-active times compared to higher lactation cows (Lact 3+) (P = 0.006). Fewer differences were found within each category relevant to day of diagnosis, yet there was a trend at the beginning of the study (group pre) between lactation 1 and cows with three or more lactations (P = 0.05).

Cows with DD showed greater variation in non-active behavior when comparing the effect of lactation number. Prior to day of diagnosis (pre), cows with higher lactation numbers exhibited more non-active behavior. Cows with one lactation had a mean non-active time of 6.69 ± 0.47 h/day while cows with three or more lactations had a mean of 7.63 ± 0.51 h/day. Upon diagnosis on day 0, cows with two lactations had more time spent non-active than those with one lactation (P = 0.04). Cows with two lactations spent 1.39 ± 0.66 h/day more mean non-active time than those with one lactation (P

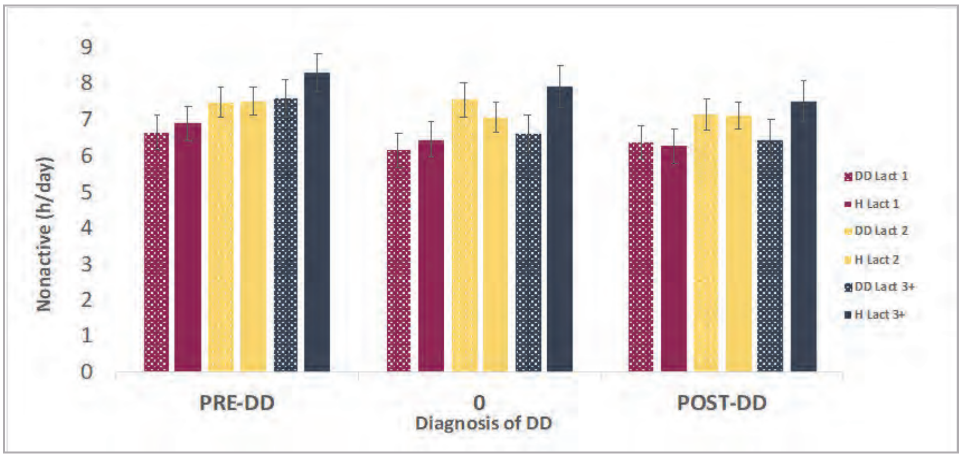

*Figure 1. Mean non-active behavior for cows with DD (n = 21) and healthy (n = 21) cows with different lactation numbers and grouped by period relative to diagnosis (pre-diagnosis, 0/day of diagnosis, and post-diagnosis). * P = 0.02.*

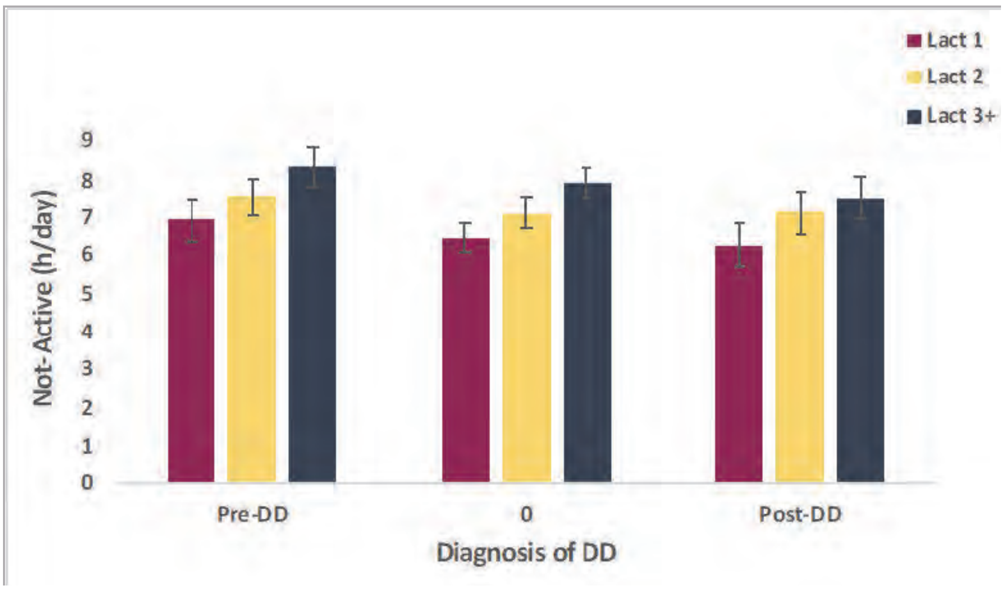

Figure 2. Mean non-active behavior for healthy cows (n=21) and DD cows (n=21) with different lactation numbers and grouped by period relative to diagnosis (pre-diagnosis, 0/ day of diagnosis, and post-diagnosis).

= 0.04). Cows with three or more lactations exhibited 0.96±0.70 h/day less non-active behavior than those in lactation two. Similarly, cows with two lactations spent more time non-active than cows with one or three or more lactations post-DD diagnosis. When comparing non-active behavior among cows with DD, cows with three or more lactations pre-diagnosis of DD had less non-active time than post-diagnosis (P = 0.005).

High active behavior

A three-way interaction was detected for high active behavior among hoof health, lactation number, and day relative to DD diagnosis (P = 0.05; Figure 3).

Healthy cows demonstrated changes in high active behavior at different lactation numbers. Generally, cows with one lactation had greater than or equal to high-active time compared to cows with two and three or more lactations with the highest mean of 3.04 ± 0.31 h/day. When assessing differences in DD cows pre-diagnosis of DD, differences were noticed between cows with one lactation and three or more lactations (P = 0.02). When comparing cows within group day 0, DD cows with one lactation had an increase in mean high active time of 1.37 ± 0.46 h/day compared to cows with three or more lactations (P = 0.004). DD cows with one lactation post day of diagnosis also showed higher high active time compared to those with two lactations (P = 0.01) and three or more lactations (P = 0.03). Not many differences were seen within stages of lactation with the exception of DD cows with two lactations. Comparison between 0 day of diagnosis and post day of diagnosis yielded an increase of high active time by a mean of 0.37±0.15 h/day (P = 0.02). Fewer differences were noticed when comparing healthy and DD cows within pre-DD, 0, and post-DD. Upon day of diagnosis a significant increase in high-active behavior was shown amongst first lactation cows (P = 0.02).

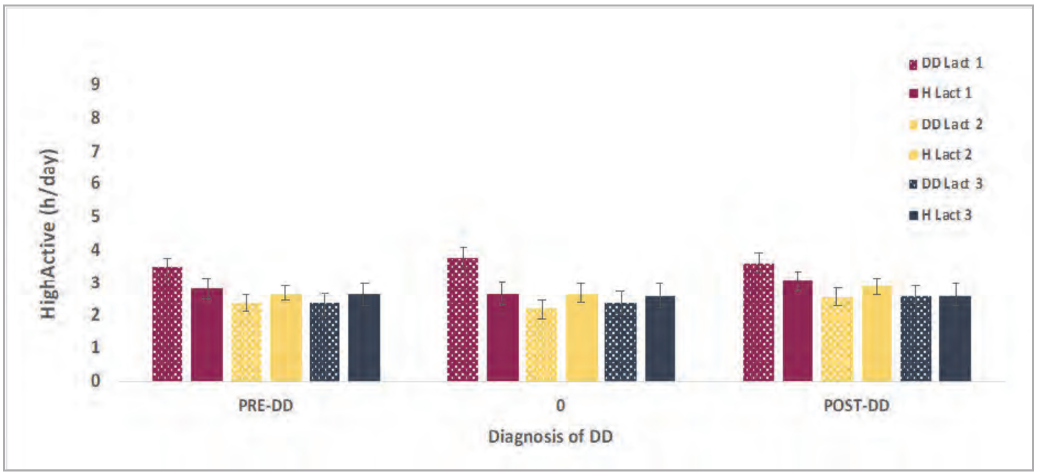

Figure 3. Mean high active behavior for cows with DD (n = 21) and healthy (n = 21) cows with different lactation numbers and grouped by period relative to diagnosis (pre-diagnosis, 0/day of diagnosis, and post-diagnosis).

Eating behavior

A two-way interaction among day relevant to diagnosis of DD and hoof health was detected for eating behavior (P < 0.0001). Cows that were healthy showed highest eating behavior with a mean eating time of 3.59±0.24 h/day. DD cows showed increase in eating behavior as progression of DD occurred. At pre-DD, cows had a mean eating time of 3.13±0.24 h/day and increased upon day 0 of DD to 3.47±0.25 h/day (P = 0.004). Post-DD eating behavior increased by 0.03±0.11 h/day, yet was not significant. When comparing DD cows at the beginning of the study within group pre-DD and post-DD, eating behavior increased by a mean of 0.37±0.11 h/day (P = 0.0009).

Active behavior

A two-way interaction was observed between hoof health and day relevant to DD diagnosis for active behavior (P < 0.0001). Within pre-DD, day 0, and post-DD, no significant differences were shown between healthy and DD cows, yet differences are seen between day of DD and DD cows. Pre-DD cows showed 0.23±0.08 h/day less mean active time than on day 0 (P = 0.004). After initial diagnosis on day 0, DD cows slightly increased in mean active time (0.002±0.08 h/day) but was not significant. When comparing pre-DD cows to post-DD cows, differences indicated an increase of 0.23±0.07 h/day (P = 0.003). When comparing healthy and DD cows at different days of diagnosis, healthy cows had lower mean active time then DD cows at day 0 of DD. Mean active time increased by 0.28±0.12 h/day upon diagnosis of DD (P = 0.03). Comparing healthy cows at the beginning of the study and DD cows at the end of the study (post-DD) showed an increase of 0.28±0.12 h/day in mean active time (P = 0.02).

Onset of DD

High active behavior

Linear regression model indicated a difference in high active behavior and day relative to diagnosis of DD (P = 0.04). When comparing high active behavior, a slight negative relationship was determined as cows approached initial day of DD. As cows neared the day of DD diagnosis, they spent 2.58 h/day less time being high active. Although there was a significant relationship between high active behavior and day, R^2 (0.023) remained low.

Eating behavior

Linear regression model indicated a difference in eating behavior and day relative to diagnosis of DD (P = 0.002). As cows neared the day of DD diagnosis, they spent 3.30 h/day more time eating. When comparing eating behavior, a slight positive correlation was determined as cows approached initial day of DD. Although there was a significant correlation between eating behavior and day, R2 (0.0496) remained low.

Discussion

In this study, healthy cows spent an average of 7.25 ± 1.48 h/day being non-active, which is similar to a study that discovered a range of 7.2 to 9.34 h/day of non-active behavior for cows (Bikker *et al.*, 2014). Studies have found healthy cows spend 3.2 to 5.4 h/day eating which is also similar to those included in this study (3.22 ± 1.24 h/day; Gomez and Cook, 2010).

Although ruminating time was not significant in this study, the mean time was within the range of those seen in previous studies (8.62 ± 1.14 h/day; Reynolds *et al.*, 2019). Bikker and colleagues (2014) grouped high-active and active behavior into one behavior category and found that cows spend, on average, 3.58 h/day being active, which is slightly higher in comparison to the average time spent active for cows in this study (2.51 ± 0.80 h/day). Interestingly, healthy cows at the beginning of the study (group Pre) had lower active time compared to those at the end of the study. This study was conducted over the summer and studies have demonstrated that heat stress can cause changes in normal behaviors such as activity time (Zahner *et al.*, 2004; Cook *et al.*, 2007). The use of stored weather data at three different times points within the study demonstrated temperature changes. At the beginning of the study temperatures averaged 19°C, increased half way through (24°C) as well as at the end of the study (30°C)(Accuweather, n.d).

The data in this study also showed variation in inactive and high active time at different stages of lactation in healthy cows. Cows with higher lactation numbers (3+) displayed more inactive behavior relative to day of diagnosis. Overall, cows in lactations 1 and 2 had more time spent high active compared to those with three or more lactations. This behavior is similar to those seen in other articles that tested for the effects of age on normal behaviors. Steensels *et al.* (2012) concluded that lying time was increased with age by 29 min/day in cows with three or more lactations compared to those with only two lactations. In general, studies determined that animals exhibited less active behavior as they become older (Ingram, 2000). In addition, the increase in high-active time of younger cows may be a response from competition and dominance produced from older cows if competing for space. Cows are social animals that will create hierarchies dependent on their ability and willingness to establish dominance. In cases where space may be limited, cows will compete and may put forth aggressive behavior such as bunting and pushing, forcing cows to become more active (Phillips and Rind, 2002; Kondo *et al.*, 1989). An indication of weakness in cows will be taken as an opportunity to challenge each other and achieve a rise in hierarchy.

Weaknesses in cattle can include signs of illnesses such as DD and/or calving where some studies had noted that cows will be weakened by parturition and sudden change of lactation (Lamb, 1976). Cows with DD generally display signs of lameness such as changes in gait that may be noticed by other cows. When comparing activity time in cows with DD and stages of lactation, first lactation cows seemed to be impacted the most upon diagnosis of DD. On Day 0 and Post-DD, lactation 1 cows exhibited less inactive and more high-active behavior then lactations 2 or 3+ cows. Previous studies noted age as an additional point of weakness as they are generally smaller and more timid, making it less likely for them to elicit an aggressive response (Lamb, 1976).

The current findings of healthy and DD cows indicated an impact of disease on normal inactive and eating behaviors. DD cows with three or more lactations showed less inactive behavior compared to their healthy counterpart within Day 0 and Post-DD. DD lesions have been associated with high amounts of pain which could influence these behaviors (Palmer and O'Connel, 2015). Additionally, DD cows showed more eating behavior Post-DD compared to healthy counterparts. These findings differ from those in previous studies that compared lame cows to healthy ones (Weigele *et al.*, 2018). Generally, it is expected that cows with pain would increase their inactive time, spending more time lying compared to healthy cows, yet some studies correlated an increase in active behavior to the increase in shorter strides cows take in order to reduce discomfort (Alsaaod *et al.*, 2012).

Analysis of the onset of DD in cows showed differences in variability of active and eating behaviors in the days leading up to the first day of DD diagnosis (Day 0), but did not for rumination, inactive, and high-active behaviors. On days prior to DD, cows showed more active behavior than on the day of DD diagnosis. This is interesting as it describes a different relationship than the one seen in the previous cohort. The relationship seen in these cows is one that is expected as the development of DD occurs. Previous studies that assessed behaviors in lame cows noted the decrease in active behavior over time (Weigele *et al.*, 2018; Van Nuffel *et al.*, 2015). Mazrier *et al.* (2006) used pedometry in an attempt to detect the onset of lameness in dairy cows and found that lame cows showed a reduction in pedometry activity 7 to 10 days prior to any clinical signs. Eating behavior maintained a positive correlation as the progression of DD occurred in this study. Cows exhibited less eating time compared to those on Day 0 of DD, which differs from previous studies of lameness (Weigele *et al*., 2018).

Conclusion

The objectives of this study were to determine if precision monitoring systems such as behavioral monitoring systems could provide insight into the detection of digital dermatitis in dairy cows. Ear monitoring systems provided behavioral data that could be used to identify shifts in normal behaviors compared to healthy cows and within the onset DD cohort. When comparing DD cows to healthy ones, some behavioral patterns differed upon day of diagnosis and post-DD diagnosis. Onset DD cows demonstrated changes in behavior prior to initial day of DD. Interestingly, differences in behaviors were seen between different lactation numbers of healthy cows and among DD cows. Overall, the use of precision technology could be beneficial in the detection of digital dermatitis of dairy cows. Future research should assess the behaviors of cows with DD in a longer study. Lameness scoring throughout the entire study could help determine differences between healthy and DD cows as well as changes in the onset of DD cows.

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