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Behavior and productivity of cows milked in automated systems before diagnosis of health disorders in early lactation

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ABSTRACT

Associations of electronically recorded data were examined before diagnosis of health disorders in early-lactation cows in herds with automated milking systems (AMS). Rumination time, activity, and milk yield data were collected for 8 mo for 605 early-lactation cows in 9 commercial AMS herds. Using multivariable generalized linear regression models controlling for parity and days in milk, data were examined relative to the day of diagnosis for health disorders occurring in absence of, or at least 14 d before, another disorder: mastitis ($n = 13$), new cases of lameness ($n = 45$), subclinical ketosis (SCK; $n = 113$), and purulent vaginal discharge ($n = 49$). All cases of displaced abomasum (DA; $n = 8$) occurred in conjunction with other disorders. Deviations from baseline among affected cows were examined, as well as differences compared with a group of healthy cows and an average group of all cows, who were given mock diagnosis days using the mean days in milk at diagnosis for each disorder. On 6 to 14 d of the 2 wk before diagnosis, cows with DA or mastitis had lower milk yield, rumination time, milking frequency, activity, and milk temperature compared with healthy cows as well as deviations from their own baseline rumination time and milk yield starting 4 to 12 d before diagnosis. Cows with DA had lower AMS supplement intake than healthy cows and deviations from their baseline activity and milk temperature starting 6 and 4 d before diagnosis, respectively. Cows with mastitis had greater milk conductivity than healthy cows and deviated from their baseline milking frequency and conductivity 8 and 12 d before diagnosis, respectively. Compared with healthy cows, those with SCK or new cases of lameness generally had lower milk yield, rumination time, milk tem-

perature, supplement intake, and milking and refusal frequencies. Only the milk temperature of lame cows deviated from baseline. Thus, acute health disorders (i.e., DA and mastitis) were associated with deviations from those cows' baseline AMS data, whereas more chronic disorders (i.e., SCK and lameness) were associated with significant but subtle longer term changes in milk production and behavior. Because cows with health disorders deviated from a group of healthy cows before they deviated from their own baseline and from the average of all other cows, including a healthy reference group in health alerts could refine the ability of detection models to identify subtle deviations in early lactation.

Key words: robotic milking, behavior, health disorder, detection

INTRODUCTION

Automated (robotic) milking systems (AMS) collect a vast amount of cow-level data and are often coupled with behavioral monitoring systems (Jacobs and Siegford, 2012). Using these data, many alerts and attention lists are generated to identify cows at risk for developing health problems. Previous research, regardless of milking system, has been focused mostly on detection of mastitis or locomotion problems, with fewer studies looking at metabolic disorders (Rutten et al., 2013). Furthermore, there is little evidence to support which indicators should be used to detect locomotion and metabolic problems (Rutten et al., 2013). Additionally, not all alerts have been validated transparently, nor do they use multiple variables and potentially important covariates (e.g., parity, DIM; King et al., 2017b). For credibility, accuracy, and repeatability, science-based recommendations are needed to generate health attention reports and to select settings for on-farm application, such as the recent development (Kamphuis et al., 2013) and field validation (Kamphuis et al., 2016) of an inline detection system for mastitis and high SCC. Those researchers also consulted industry representa-

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tives for feedback to improve the application of those models (Kamphuis et al., 2016).

Researchers have previously examined associations of changes in rumination, activity, and milk yield data with health disorders in dairy cows, but fewer studies have created and validated prediction models. Daily milk production data followed obvious patterns before and up to 7 d after clinical ketosis diagnosis (Gröhn et al., 1999) but were less responsive to cases of subclinical ketosis (**SCK**) and metritis (Gáspárdy et al., 2014). Daily rumination time and BW data changed relative to the day of SCK and metritis diagnoses (Gáspárdy et al., 2014). Rumination time has been shown to decline with the onset of many health disorders, such as mastitis (Fogsgaard et al., 2012; Soriani et al., 2012), inflammatory conditions, metabolic disorders (Soriani et al., 2012), SCK, retained placenta, and metritis (Liboreiro et al., 2015); however, data preceding diagnoses are inherently more useful for earlier diagnoses and intervention if they can predict risk or detect disease more efficiently than the observation of clinical signs. Compared with healthy cows, those diagnosed postpartum with SCK, metritis, or other disorders have been shown to spend less time ruminating before calving (Kaufman et al., 2016; Schirmann et al., 2016). Although there were no differences in prepartum activity between healthy cows and those that later developed SCK, retained placenta, or metritis, the afflicted cows were shown to be less active after calving (Liboreiro et al., 2015). Prior to diagnoses of SCK, displaced abomasum (**DA**), and digestive disorders, milk yield began to decline approximately 5 to 7 d before diagnosis and activity started to decline 8 to 9 d beforehand (Edwards and Tozer, 2004). King et al. (2017b) explored associations of productivity and behavior data before health problems in an AMS herd and found that rumination, activity, and BW data could potentially help to identify DA, pneumonia, SCK, and metritis before changes in milk yield.

Longitudinal milk yield and activity data assessed relative to the day of diagnosis have had great predictive value for detection of lameness when combined with rumination time of parlor-milked cows (Van Herrem et al., 2013) or milk flow rate and AMS teat cup attachment speed (Garcia et al., 2014). Steensels et al. (2016) used a decision tree model to detect ketosis and metritis in AMS-milked cows using milk yield, rumination time, activity, milk slope, and current BW relative to BW at calving to predict the probability of illness. Steensels et al. (2017) also studied health disorders in parlor-milked cows, reporting large differences in rumination time, activity, and milk yield between 5 health status groups (healthy, ketosis, metritis, lameness, and other disorders). Finally, Stangaferro et al. (2016a,b,c)

assessed a health index score, comprising rumination and activity data, to detect DA, ketosis, indigestion, mastitis, or metritis. Because the response of individual variables can vary by the type and severity of health disorder (Stangaferro et al., 2016a,b,c), it is possible that predictive models could not only identify cows with potential health problems but perhaps also indicate the type of problem.

Few studies examining behavior and production variables before illness diagnoses have been conducted in AMS (Garcia et al., 2014; Steensels et al., 2016; King et al., 2017b), and those studies consisted of only 1 herd each. Moreover, no large-scale study examined the use of milk yield, rumination, activity, or other electronically collected data to predict a variety of health disorders in AMS herds. Although the overall effects of illness may be similar for AMS and conventionally milked cows, the behavioral freedom associated with free cow traffic and individualized milking could augment the response in AMS because cows are able to extend their milking interval much longer than a conventionally milked cow could.

Therefore, the objective of this study was to examine associations of numerous electronically recorded variables to identify health disorders in early-lactation cows milked by AMS. Rumination, activity, milk yield, and BW data were examined relative to diagnoses of SCK, DA, severe endometritis or purulent vaginal discharge (**PVD**), lameness, and mastitis with the hypothesis that deviations in those variables would occur before diagnosis. The degree to which each variable deviated was expected to vary by disorder, and we predicted that certain variables would not deviate at all before specific diagnoses. It was further expected that sick cows would deviate from their own healthy baseline at a different time relative to when they deviated from a group of healthy cows but that this could also differ by variable. We also hypothesized that sick cows would deviate from a group of healthy cows before deviating from the average of all other cows.

MATERIALS AND METHODS

Farms, Animals, and Housing

This study was approved by the University of Guelph Research Ethics Board (no. 14AP015) and the University of Guelph Animal Care Committee (AUP no. 3140). Farms were selected based on the criteria that they (1) milk Holstein cows exclusively in an AMS (Lely Astronaut A4, Lely Industries N.V., Maassluis, the Netherlands), (2) have done so for a minimum of 6 mo, and (3) use the AMS rumination monitoring

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