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Prepartal standing behavior as a parameter for early detection of postpartal subclinical ketosis associated with inflammation and liver function biomarkers in peripartal dairy cows

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ABSTRACT

A degree of negative energy balance is commonly experienced by cows during early lactation. This physiological state, if pronounced or prolonged, leads to partial oxidation of nonesterified fatty acids as an energy source and, consequently, increasing blood β-hydroxybutyrate (BHB) concentrations and potentially development of ketosis in postpartal dairy cows. Twenty-four multiparous Holstein cows received a common prepartal and postpartal diet. Cows were fitted with an accelerometer mounted laterally on the distal left hind leg using vet wrap from −30 to 15 d relative to parturition. A retrospective analysis was performed using the postpartal BHB data at 8 time points from 0 to 15 d in milk measured with the Precision Xtra (Abbott Diabetes Care, Alameda, CA). Cows with an average blood BHB <1.4 mmol/L were designated nonketotic (NONKET; n = 12), and those with ≥1.4 mmol/L were designated ketotic (KET; n = 12). A total of 8 samples per cow were used for this analysis. Subsequent analyses of behavioral patterns and blood biomarkers were performed using this group effect. On average, blood BHB reached subclinical levels (1.4 ± 0.3 mmol/L; mean ± standard error of the mean) at 3 d postpartum for all cows in this study. Behavioral patterns were obtained from accelerometer data, and correlation analysis was performed between these behaviors such as standing and lying time from −30 to 3 d relative to parturition and blood BHB concentration at 3 d postpartum. The strongest correlation was obtained between standing time at 3 d before calving and blood BHB at 3 d postpartum. Dry matter intake was greater (ca. 3 kg/d) in NONKET cows than in KET cows. An interaction of group × time for milk yield resulted in an overall increase of 5.7 kg/d in NONKET cows in comparison with KET. The blood concentrations of biomarkers for liver function (γ-glutamyltransferase and glutamic-oxaloacetic transaminase), inflammation (IL-6), and metabolism (nonesterified fatty acids) were increased at various time points in KET cows in comparison with NONKET during the transition period. Overall, lower bilirubin in NONKET cows than in KET further confirmed an impaired liver function in the latter group of cows. Our findings revealed the potential for establishing correlations between prepartal behavioral patterns derived from accelerometer data and postpartal subclinical ketosis, and further confirming the latter by physiological alterations in biomarkers related to inflammation and liver function. Our data also indicate that cows with a predisposition to postpartal subclinical or clinical ketosis will remain standing for fewer hours during the days leading to parturition, which decreased DMI, and this condition was further reflected in lower milk yield.
Key words: transition cow, subclinical ketosis, behavior

INTRODUCTION

The most challenging period in the lactation cycle of dairy cows occurs during the transition period from late gestation to early lactation. During this transition, cows experience various physiological and metabolic adaptations such as insulin resistance, reduced feed intake and immune function, and negative energy balance (**NEB**; Drackley, 1999). Negative energy balance results when energy requirements to sustain milk production during early lactation are not met by the energy intake (Herdt, 2000; McArt et al., 2013a). Cows undergoing NEB will experience increased lipolysis in fat stores and, consequently, increased production of nonesterified fatty acids (**NEFA**) that will be taken up by the liver.

Prolonged periods with high blood NEFA concentrations reaching the liver will eventually impair the

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ability of the liver to completely oxidize NEFA; this response is evidenced by increased blood ketone bodies (i.e., BHB, acetoacetate, and acetone), which are the product of partially oxidized NEFA. Cows experiencing high ketones levels (>1.4 mmol/L) in blood through the first 2 wk after calving are potentially at risk of developing clinical ketosis and are at increased risk to develop other postpartal diseases such as displaced abomasum and metritis (LeBlanc, 2010; Seifi et al., 2011). This scenario is likely to result in lower conception rates at first service and lower milk production in early lactation, dampening the profitability of any dairy operation (McLaren et al., 2006).

Currently, prepartal blood NEFA concentration is one of the most reliable tools to predict which cows are at risk of developing postpartal diseases (Ospina et al., 2010; Chapinal et al., 2011); however, the ability to measure this biomarker in a dairy-farm setting is limited, not practical, and time consuming. After calving, one of the preferred tests for monitoring subclinical ketosis is the hand-held Precision Xtra (validated by Iwersen et al., 2009; Abbott Diabetes Care, Alameda, CA), which measures blood BHB concentration. Unfortunately, the onset of ketosis can be either gradual or acute, depending on several conditions such BCS at calving, amount of NEFA mobilization, stress conditions, and inflammatory challenges (Trevisi et al., 2016). Therefore, parameters that can accurately predict whether cows are at risk of developing ketosis will give a significant advantage to dairy farmers.

Ketosis is a common postpartal disease in dairy cows, which is highly associated with liver function or the capacity of the liver to metabolize the surge of NEFA reaching the liver during the transition period. Thus, inflammatory conditions during the transition period of dairy cows have been commonly observed to impair liver function, and these conditions can considerably exacerbate metabolic disorders such as ketosis (Bertoni et al., 2008). The specific relationship between inflammation and ketosis has been investigated by Abuajamieh et al. (2016), where a consistent increase in inflammatory biomarkers (i.e., serum amyloid A and haptoglobin) and BHB was observed in ketotic cows. Therefore, it is conceivable that the increased synthesis and production of inflammatory biomarkers in the liver can diminish its functional capacity and render this organ unable to face the need to metabolize the excess NEFA and, consequently, increase ketone synthesis (Trevisi et al., 2012).

Prepartal behavioral patterns, such as standing and lying time budgets, of dairy cows monitored through sensor systems had shown promising results on predicting which cows are at risk of developing subclinical ketosis after calving (Goldhawk et al., 2009; Itle et al., 2015; Kaufman et al., 2016b). In fact, sensor systems that record acceleration in the 3 axes (i.e., X, Y, and Z) have been previously validated for recognition of various behavioral patterns in dairy cows (Ledgerwood et al., 2010), and similar sensor systems have already been implemented on commercial dairy farms. However, much still needs to be improved on the use of behavioral data derived from accelerometers to predict ketosis, for instance, combining these data with blood biomarker profiling related to aspects of inflammation, oxidative stress, and liver function. Indeed, little information currently exists on blood biomarkers and the physiological adaptations aforementioned during the onset of ketosis. Therefore, the objective of this study was to determine which behavioral patterns derived from accelerometer data, such as standing behavior and lying behavior, in peripartal dairy cows could allow early detection of subclinical ketosis during the days leading to the onset of this condition.

MATERIALS AND METHODS

Experimental Design and Retrospective Analysis

All the protocols for this study (protocol no. 12097) were approved by The Institutional Animal Care and Use Committee. Details for the original experimental design to test the effects of metal AA complexes fed to transition dairy cows have been published previously (Osorio et al., 2016). Briefly, 44 multiparous Holstein cows were enrolled at 110 d before calving and offered a common diet supplemented entirely with inorganic trace minerals to meet the requirements until 30 d before calving (NRC, 2001). From 30 d before calving, cows received a common prepartal diet (1.5 Mcal/kg of DM, 15% CP), and from calving to 30 DIM cows received a common postpartal diet (1.76 Mcal/kg of DM, 18% CP). Both diets were partly supplemented with an inorganic trace mineral mix of Zn, Mn, and Cu to supply 35, 45, and 6 mg/kg, respectively, of the total DM. The remaining trace mineral supplementation to achieve 75, 65, 11, and 1 mg/kg of Zn, Mn, Cu, and Co, respectively, in the total DM was supplied via oral bolus from −30 to 30 d relative to parturition. Cows were fed individually once daily at 0630 h using an individual gate system (American Calan Inc., Northwood, NH). Cows were housed in a ventilated, enclosed barn during the dry period and had access to sand-bedded freestalls until 3 d before expected parturition, when they were moved until parturition to individual maternity pens bedded with straw. After parturition, cows were housed in a tiestall barn and fed a common lactation diet once daily. For the current study a subset of 24 cows was fitted with an accelerometer (HOBO pendant G logger;