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Use of novel sensors combining local positioning and acceleration to measure feeding behavior differences associated with lameness in dairy cattle

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ABSTRACT

Time constraints for dairy farmers are an important factor contributing to the under-detection of lameness, resulting in delayed or missed treatment of lame cows within many commercial dairy herds. Hence, a need exists for flexible and affordable cow-based sensor systems capable of monitoring behaviors such as time spent feeding, which may be affected by the onset of lameness. In this study a novel neck-mounted mobile sensor system that combines local positioning and activity (acceleration) was tested and validated on a commercial UK dairy farm. Position and activity data were collected over 5 consecutive days for 19 high-yield dairy cows (10 lame, 9 nonlame) that formed a subset of a larger (120 cow) management group housed in a freestall barn. A decision tree algorithm that included sensor-recorded position and accelerometer data was developed to classify a cow as doing 1 of 3 categories of behavior: (1) feeding, (2) not feeding, and (3) out of pen for milking. For each classified behavior the mean number of bouts, the mean bout duration, and the mean total duration across all bouts was determined on a daily basis, and also separately for the time periods in between milking (morning = 0630–1300 h; afternoon = 1430–2100 h; night = 2230–0500 h). A comparative analysis of the classified cow behaviors was undertaken using a Welch *t*-test with Benjamini-Hochberg post-hoc correction under the null hypothesis of no differences in the number or duration of behavioral bouts between the 2 test groups of lame and nonlame cows. Analysis showed that mean total daily feeding duration was significantly lower for lame cows compared with non-lame cows. Behavior was also affected by time of day with significantly lower mean total duration of feeding and higher total duration of nonfeeding in the afternoons for lame cows compared with nonlame cows. The results demonstrate how sensors that measure both position and acceleration are capable of detecting differences in feeding behavior that may be associated with lameness. Such behavioral differences could be used in the development of predictive algorithms for the prompt detection of lameness as part of a commercially viable automated behavioral monitoring system.
Key words: local positioning, 3D accelerometer, lameness, feeding behavior, dairy cow

INTRODUCTION

The welfare and economic implications of lameness on dairy farms are well documented (Whay et al., 1998; Willshire and Bell, 2009). It has been demonstrated that the prompt treatment of dairy cows reduces the severity of claw horn lesions and the number of repeat treatments required (Leach et al., 2012), therefore reducing the treatment costs and financial losses to the farmer and reducing duration and severity of pain for the cow. Ensuring cows with the early stages of lameness are recognized and then treated remains a challenge, as farmers are known to underestimate the prevalence of lameness on their farms (Leach et al., 2010) and identify and treat cows later than researchers (Leach et al., 2012).

To encourage improved detection of lameness by farmers, the Agriculture and Horticulture Development Board (**AHDB**) Dairy Mobility Score was developed in 2007 by a panel of UK dairy industry representatives and promoted as a management tool for lameness (AHDB, 2017). The most effective use of mobility scoring requires farm staff to watch all cows on a regular basis (e.g., once every 1–2 wk), but due to the time constraints farmers are often reluctant to complete the

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task as frequently as required due to other conflicting priorities (Horseman et al., 2014). As such, a need exists for systems that can automatically detect lameness at an early stage without the need for time-consuming observations. Several studies have reported lame cows showing changes to both feeding and lying behavior. Lame cows are slower to respond to food being made available (Blackie et al., 2011; Yunta et al., 2012) and feed faster, although for a reduced overall duration per day (González, 2008; Palmer et al., 2012; Norring et al., 2014). Lameness in dairy cows is also associated with changes in lying behavior, although these results are more equivocal (increased lying: Singh et al., 1993; Galindo and Broom, 2002; Blackie et al., 2011; no difference: Ito et al., 2010; Yunta et al., 2012; decreased lying: Cook et al., 2008). Therefore, automated monitoring of individual cow behaviors may potentially offer the opportunity for the early detection of lameness.

Recent attempts to use automated systems to detect lameness have generally relied upon the identification of abnormal gait using load cells, pressure-sensitive mats, computer vision, or accelerometers (reviewed by Van Nuffel et al., 2015). Automated monitoring and assessment of feeding behavior in cattle has relied on electronic feed troughs (Palmer et al., 2012; Norring et al., 2014), which are uncommon on commercial dairy units due to installation costs. Triaxial accelerometers are embedded in several commercial dairy applications for the detection of estrus activity and other behaviors (Silper et al., 2015), and have been used to detect changes in lying and standing behavior associated with lameness (e.g., Blackie et al., 2011; Navarro et al., 2013). Accelerometers have also been used to classify and monitor changes in rumination and feeding activity (Van Hertem et al., 2013; Vázquez Diosdado et al., 2015; Mattachini et al., 2016).

Several studies have employed sensor systems to monitor the location of dairy cattle using different methods including GPS for pasture-based animals (Williams et al., 2016) and various real time location system (**RTLS**) radio frequency-based technologies for indoor sensing (Gygax et al., 2007; Alarifi et al., 2016; Shane et al., 2016; Meunier et al., 2017). Although validated for use on farms (e.g., Tullo et al., 2016), very few studies have examined at the application of these systems in dairy management or combined RTLS location data with activity data recorded from accelerometers. Arcidiacono et al. (2017) reported the potential for RTLS to detect estrus in dairy cows and suggested that other applications might include monitoring disease or verifying the welfare status of cows.

Automated classification of cow behavior typically requires some form of processing of the raw location or accelerometer data using a statistical or computational procedure (machine-learning techniques). For example, Martiskainen et al. (2009) developed a method that uses multiclass support vector machines to automatically classify accelerometer data into several types of dairy cow behavior, but the support vector machines algorithm has a large computational cost. Robert et al. (2009) implemented a more computationally efficient rule-based decision tree algorithm to classify different behaviors in cattle, although they could not classify feeding behavior due to the use of a leg-mounted accelerometer. Vázquez Diosdado et al. (2015) developed a simple rule-based decision tree for classifying accelerometer data, collected using the same neck-mounted sensors used in the current study, and found that feeding behavior could be identified with high acceleration due to the lifting and lowering of the head. However, Vázquez Diosdado et al. (2015) did not directly consider how location data could be combined with the accelerometer data to improve the classification of feeding and other types of behavior.

The aim of the current study was to assess the capability of a novel real-time location sensor and combined accelerometer to measure potential differences in behavior (specifically total feeding duration, feeding bout length, and number of feeding bouts) for lame and nonlame cows within a freestall housing environment.

MATERIALS AND METHODS

Study Farm and Selection of Animals

All experimental work was undertaken in a freestall barn on a commercial UK dairy farm measuring 30 × 58 m, which housed approximately 210 cows in 2 (high and low yield) groups separated by a central feed alley (Figure 1a). The high-yield group consisted of 120 cows with access to 120 freestalls and feed space of 0.43 m/cow in the upper barn area (Figure 1a). The lower-yield group consisted of 90 cows with access to 90 freestalls and feed space of 0.58 m/cow in the lower barn area (Figure 1a). All cows were pedigree Holstein with a herd average 305-d yield of 11,000 L/cow. Cows were milked 3 times a day (0500, 1300, and 2100 h) and were fed a commercial TMR. Feed was delivered once per day (ready for cows returning from morning milking) and pushed up a further 4 to 5 times throughout the day. All cows received a corrective claw trim in the first 60 d of lactation by a contract claw trimmer who visited the farm approximately every 6 wk.

Two separate cohorts of cows were selected for the purpose of this study. A small trial cohort of 9 cows from the high-yielding group were used for the validation of sensor position (Supplemental File S1; https://doi.org/10.3168/jds.2016-12172) and to provide position and