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Technical note: Validation of sensor-recorded lying bouts in lactating dairy cows using a 2-sensor approach

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ABSTRACT

Lying behavior is a relevant indicator for the evaluation of cow welfare. Lying can be recorded automatically by data loggers attached to one of the hind legs of a cow. A threshold for the duration of a lying bout (LB) record is required, however, to discard false records caused by horizontal leg movements, such as scratching. Previously determined thresholds for similar sensors ranged from 25 s to 4 min. We aimed to validate LB recorded by the IceQube sensor (with IceManager software; IceRobotics, South Queensferry, UK) and to determine a threshold to distinguish true from false LB records in lactating dairy cows. A novel method of validation, which does not require time-consuming behavioral observations, was used to generate a larger data set with potentially more incidental short LB records. Both hind legs of 28 lactating dairy cows were equipped with an IceQube sensor for a period of 6 d and used as each other's validation. Classification of LB records as true (actual LB) or false (recorded while standing) was based on 3 assumptions. First, all standing records (absence of LB records) were assumed to occur while standing. Second, false LB records due to short leg movements could not occur in both hind legs simultaneously. Third, true LB only occurred if the LB records of the paired sensors coincided. False LB records constituted 4% of the records. Based on a maximum accuracy of 0.99, a minimum duration of LB records of 33 s was determined, implying a sensitivity of 0.99 and a specificity of 0.98. Applying this threshold of 33 s hardly affected estimates of daily lying time, but improved estimates of frequency and mean duration of LB for individual cows. The importance of distinguishing short LB was demonstrated specifically for detection of calving. The 2-sensor approach, using sensor outputs on both hind legs as each other's validation, is a time-efficient method to validate LB records that can be applied to different sensors and husbandry conditions.

Key words: dairy cow, sensor, validation, lying behavior

Technical Note

Diseases, housing conditions, stocking density, temperature, and several other factors can cause changes in lying behavior (EFSA, 2009). Assessing lying behavior, therefore, can yield insight into the welfare of dairy cows. Lameness, for example, has been associated with an increase in total lying time (Ito et al., 2010). Furthermore, cows that had a difficult calf delivery alternated between lying and standing more often, resulting in a higher number of lying periods or lying bouts (**LB**) per day (Proudfoot et al., 2009).

Currently, lying behavior can be assessed using continuous observations from video recordings or data from sensors. Sensors have the potential to record lying behavior automatically, thus time efficiently. In addition, increasing use of activity sensors for estrus detection leads to an increasing on-farm presence of sensors that could also record lying behavior (Steeneveld and Hogeveen, 2015). Validation of the sensor output is necessary, however, to ensure that recorded data accurately reflect true behavior. Lying bout records have been validated against the gold standard of time-consuming behavioral observations to determine a threshold that retains true and discards false records (Trénel et al., 2009; Ledgerwood et al., 2010; Tolkamp et al., 2010; Mattachini et al., 2013). In other studies, however, thresholds are not used or not underpinned by scientific validations (Endres and Barberg, 2007; Ito et al., 2010; Blackie et al., 2011; Kokin et al., 2014).

IceTag sensors (IceRobotics, South Queensferry, UK), attached to one of the hind legs of a cow, have been used to record activity and lying behavior by several research groups (Endres and Barberg, 2007; Tolkamp et al., 2010; Blackie et al., 2011; Mattachini et al., 2013). Tolkamp et al. (2010) validated IceTag LB records against continuous observations of late-

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pregnant beef cows. They transformed data about the percentage of lying and standing per minute into lying episodes per second and defined a threshold of 4 min to discard false episodes. This threshold reduced the number of lying episodes with 62 to 88%. Later, IceTag-data were produced per second and a threshold of 25 s was validated for dairy cows by Mattachini et al. (2013). The new IceManager software (2010) for the IceTag and similar IceQube sensor, which replaced IceTagAnalyser software, automatically creates a separate file with recorded LB. No LB record threshold has been formulated or validation performed for these LB records.

Thresholds for sensor output of lying behavior have been validated, so far, against behavioral observations (Ledgerwood et al., 2010; Tolkamp et al., 2010; Mattachini et al., 2013). Because behavioral observations take time, however, data sets to validate sensor output are often small (Trénel et al., 2009; Mattachini et al., 2013). Incidental short LB may not be observed frequently enough in such a data set to influence the threshold, while their detection will depend on it. Moreover, short LB could be highly relevant to detect as an indicator for acute discomfort or restlessness. Therefore, a larger data set would be more suitable to establish an optimal threshold to ensure that sensor data accurately reflect lying behavior.

We aimed to validate LB recorded by the IceQube sensor and to determine an optimal threshold to distinguish true from false LB records in lactating dairy cows. Moreover, to generate a larger data set that potentially includes more incidental short LB, we used a time-efficient novel method of validation that does not require behavioral observations. In addition, we specifically analyzed LB records of periparturient cows to illustrate the importance of detection of short LB.

Experimental Setup and Data Collection

In October and November 2014, data from 28 cows were obtained on the research farm Dairy Campus in Lelystad (the Netherlands). Cows were housed in free stalls with mattress and sawdust bedding and concrete slatted floors. They were milked twice daily and supplied with fixed amounts of concentrates and ad libitum roughage. Stage of lactation ranged from 20 to 133 DIM (90 ± 29, mean ± SD). Parity ranged from 2 to 6 (3.3 ± 1.1). Cows were equipped with 2 IceQube sensors (IceRobotics) simultaneously. Sensors were attached to the left and the right hind leg of each cow, for a period of 7 d, yielding paired records per cow. On November 7, 2014, the research farm was declared to have a *Salmonella* outbreak. Two weeks before that, fever and diarrhea were already observed in the herd. It is unclear how many animals were infected. Diseases could affect total lying time, but are not expected to interfere with the recording and validation of LB data. Therefore, data from all cows were included. One cow died, resulting in only 1 complete day of recording.

To illustrate the importance of detecting short LB, we analyzed IceQube LB records around calving (2 d before until 2 d after calving) from another 6 cows that calved on the research farm between August 2014 and July 2015.

IceReader (hardware; IceRobotics) was used to download IceQube data, and IceManager (software; IceRobotics) processed these data into LB records, with a start date, start time (hh:mm:ss) and duration (s). Per sensor, a file with LB records and a file with the number of LB recorded and lying time per day were produced. This output differs from earlier versions of IceTagAnalyser software, which only yielded the percentage of lying and standing recorded on a per-minute or per-second basis. The yet unvalidated LB records are referred to as raw LB records. Data were processed and analyzed in SAS (version 9.3, SAS Institute Inc., Cary, NC). The analysis at the LB record level included raw LB records collected from the 12 h following attachment of IceQube sensors, and from the subsequent 6 complete days. For analyses of lying time and LB frequency per day, only the 163 (27 cows 6 d and 1 cow 1 d) completely recorded days were included.

Classification of raw LB records as true (actual lying) or false (recorded while standing) LB was based on 3 assumptions. First, all standing records (i.e., absence of a raw LB record between 2 consecutive raw LB records) were assumed to occur while standing (Tolkamp et al., 2010). Second, false LB records due to short leg movements from a vertical to a horizontal position could not occur in both hind legs simultaneously. Third, following from the first 2 assumptions, true LB only occurred if lying was recorded on both hind legs, thus when LB records of the paired sensors coincided. To classify the raw LB records, all were combined in one file and sorted by cow, start date, and start time. If the start date, start time, and duration of a raw LB record by the sensor on the right hind leg (**R**) were identical to a raw LB record by the sensor on the left hind leg (**L**) of the same cow, they were classified as a true LB record and assumed to correspond to a LB. However, start time and duration of coinciding raw LB records by R and L could differ slightly. This difference could be due to differences in leg movements when lying down and getting up, or could result from minor differences in the internal clock of both sensors. Therefore, the allowed difference in start time and duration was relaxed stepwise with 2 s, until 14 s, at which point all raw LB records that overlapped in time with raw LB records