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Short communication

Validating the IceRobotics IceQube tri-axial accelerometer for measuring daily lying duration in dairy calves

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ABSTRACT

The objective of this study was to test whether dairy calf daily lying durations as recorded by an automated data logger (tri-axial 4 Hz IceQube accelerometer) are equivalent to manually determined daily lying durations obtained via retrospective analysis of video recordings. This was accomplished by comparing two behavioral observation techniques (Manual Determination and Automated Determination) when applied in parallel to the same group of animals. The study comprised two stages through which (1) the significance or non-significance of differences between results from the two methodologies was established, and (2) the ability of a correction filter to potentially remove erroneous records from the sensor output data and improve equivalency was tested. Thirteen group-housed calves were studied over 96 continuous hours. The average daily lying duration for calves was 11h:37 min/calf/d (± 4h:47 m) for an average of 22 ± 6 lying bouts/d. The two methodologies were shown to be equivalent with daily lying durations between methodologies differing by < 1 min/calf/d. Correction filters applied to the sensor data output files removing lying bouts ≤ 60 s improved equivalency and reduced the number of deviating lying bouts to ≤ 5% of total bouts recorded. The optimal filter excluded lying bouts ≤ 8 s in duration. Deviations between the two methodologies were mainly due to inaccurately registered lying bouts which occurred during nested behaviors such as play, grooming/ear scratching and feeding. In summary, results obtained by use of the IceQube sensor, when coupled with a correction filter, are equivalent to manual daily lying duration observations of group-housed calves aged ~55d and suggests an opportunity to reduce the labor requirements in collecting such data, without significant impact on data quality.

1. Introduction

Daily lying duration can be an important indicator of the health and welfare status of calves. Early detection of reduced health status in practical management can allow for timely intervention potentially reducing the negative effect on the calf (Swartz et al., 2016), and benefit overall productivity (Bonk et al., 2013; Trenel et al., 2009). Previous research has used this measure as a method of assessing calf response to common management practices such as limit feeding and weaning. Vieira et al. (2008) reported that calves fed restricted amounts of milk spent 1 hr/d less lying than those fed ad libitum milk, this indicating that lower daily lying times could be used as a behavioral indicator of hunger. Gradually weaned calves were shown to have increased daily lying duration when compared with abruptly weaned calves (Jasper et al., 2008), this potentially indicating an improved adaptation to the nutritional change imposed by removal of the milk feed in gradually weaned calves. In an effort to eliminate the need to manually observe and record lying durations or to retrospectively analyze often large volumes of video footage, alternative automated recording devices have been developed and their use validated, (Bonk et al., 2013; Ledgerwood et al., 2010). Such devices record the acceleration forces generated by an animal during movement, with the raw data subsequently translated into behavioral data using algorithms. Useful outputs include standing time, lying time, an activity index, and the number of steps taken (Elischer et al., 2013; Trenel et al., 2009). Some loggers apply these algorithms automatically while others require the algorithms to be applied to the raw data after downloading the relevant output files.

Automating such data collection has a number of advantages. Firstly, manual observations are time-consuming, labor-intensive and, thus, expensive (Ledgerwood et al., 2010) meaning that automatic recording delivers a financial saving. Secondly, automated monitoring reduces inevitable subjective observer bias when recording behaviors (Muller and Schrader, 2003). However, automated devices also raise some concerns. For example: the use of sensors may not be free of bias (Rushen et al., 2012); different post-processing filtering and correction

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methods may result in some loss or exclusion of true and meaningful records (Rushen et al., 2012); and nested behaviors (e.g. stretching, grooming, feeding, play) tend to fragment or confound lying and standing behavior data (Trenel et al., 2009). Thus, it is necessary to validate the use of such sensors and ensure that the data they provide is comparable to that generated by established methodologies.

Research is emerging which aims to validate the accuracies of a range of sensors in animals of different species, ages and under varying management practices. Some of these studies use direct observations, or additional sensors, as controls and have reported high levels of agreement between the numbers of lying and standing events recorded. Bonk et al., (2013) found > 97% agreement between sensor data and reference measurements (direct observations) in calves while Mattachini et al., (2013) compared two different sensors with direct observations in dairy cows and found > 95% correlation in the number of standing/lying events recorded by the automated and manual techniques. Much of this research has led to the development of filtering protocols which are applied to the sensor's data output to remove specific activity readings in order to improve accuracy (as evaluated by correlation with controls). A growing assortment of correction filters is emerging to which, in agreement with Bonk et al. (2013), new calibration models should be added (for different sensors and management stages for example).

At a practical level, sensors that are commonly used in research may not commonly be used by farmers, due to their high cost and unnecessary capabilities. Thus, testing of sensors marketed for commercial (farm) use is desirable. The overall objective of the current study was to assess if the IceQube 4hz tri-axial accelerometer (IceRobotics, Edinburgh, Scotland), which is marketed as an activity sensor for on-farm use with adult cattle, is valid for use in recording daily lying duration in dairy calves, when worn on the leg. The test hypothesis was that two methodologies (one automated and the other, manual) used for determining daily lying duration (a function of both the number and duration of lying bouts) in calves give equivalent results. Automated Determination characterizes the daily summation of lying bouts (i.e. periods of time spent lying down) frequency and duration using an activity sensor, while Manual Bout Determination characterizes the daily summation of lying bout frequency and duration through video recording and retrospective manual analysis of the video footage. The objective was assessed over two successive methodologies: 1, application of the Bland-Altman (1983) methodology to determine if the two methodologies differ significantly via calculation of mean difference, and 2, to test if a correction filter designed to remove potentially erroneous sensor output data improves equivalency.

2. Material and methods

2.1. Animals and housing

Thirteen Holstein calves (n = 7 male; n = 6 female), of average age 55d ± 5d were randomly selected from two pens of straw-bedded weaning calves (n = 20 per pen, pen dimensions 6 m x 6 m including feeder space) which were part of a wider production trial. The selected calves were each fitted with an IceQube activity sensor (IceRobotics, Edinburgh, Scotland) on their rear right leg, and returned to the group pens. The calves were in the process of weaning off milk replacer with ad libitum concentrate meal and straw. The house was tunnel ventilated and unheated. Ambient temperature averaged 10 °C throughout the course of the study.

2.2. Data collection

Data was collected and prepared according to two methodologies, namely: Automated Determination, through which daily lying durations were calculated as a function of lying bout frequency and duration automatically determined using an activity sensor, and Manual Determination, through which lying bout frequency and duration were determined through retrospective analysis of video footage. The methodologies were applied simultaneously in order to collect data from the same calves over the same timescale, thereby generating matched samples suitable for direct statistical comparisons.

2.2.1. Automated determination

IceQube sensors are designed to be worn on the leg. However, the standard rubber leg-strap sensor housings provided as an accessory for these sensors, and marketed as suitable for cattle, were too large for the calves in the current study with potential ramifications for the quality of sensor data. The sensors were instead attached using a secure and self-bonding flexible bandage (Vet Wrap), with cushion wadding placed behind the sensor for comfort as according to Ledgerwood et al. (2010) and Bonk et al. (2013). The dimensions of the sensor after fitting were no greater than 70 mm (h) × 50 mm (w) and 45 mm (d). Sensors were fitted on the right hind leg so as not to interfere with lying comfort as discussed by Bonk et al. (2013). Both the identity of the calf (ear tag number), and serial number of the IceQube sensor worn, were recorded to ensure that sensor outputs were associable to the wearer. Sensors were worn for 4 days (96 continuous hours).

Sensors were initiated with the correct time and date. All other settings were the manufacturer's default settings as, unlike some commercially available sensors, the sampling rate of the IceQube cannot be altered. IceQube sensors measure the acceleration forces which occur during animal movements on a second-by-second basis, and algorithms are automatically applied to translate these measurements into posture and movement behavior output files consistent with a 1 s sampling rate. Data outputs downloaded from the sensors at the end of the recording period, consist of ‘summary data’ and ‘lying bout’ data. ‘Summary data’ segments the recording period into 15 min intervals with each interval carrying the following associated data: a motion index score, the amount of time spent standing, the amount of time spent lying, the number of steps taken and the number of lying bouts recorded. By contrast, ‘Lying bout’ data segments the recording period into distinct periods of lying (lying bouts), each initiated by the registering of a lying event and each concluded by the registering of a standing event. Each lying bout carries the following associated data: start date/time, end date/time, and the resulting bout duration. To compare the sensor's daily lying duration records, the ‘lying bout’ data was used. The time of fitting and time of removal of each sensor was recorded, and any data recorded by a sensor outside of these times was discarded. Daily lying durations were then calculated as a function of lying bout number and duration. Sensor data outputs were not modified further.

2.2.2. Manual determination

Calves were video-recorded throughout the 96 h that they wore the IceQube sensors. Two wide angle (3.6 mm lens) Sharp 650 tvl video cameras were used. One camera was used to cover an entire pen. The videos (800 × 600 pixel resolution) were stored digitally at 24 FPS, using an Alien H264 DVR. The video recorder's time management was synchronized with that of the IceQube sensors, and was checked daily. To aid subsequent calf identification on video, calf spot patterns were photographed before entry to the pens, and dimmed lighting was provided during darkness hours (at approximately 40% of midday light levels, based on a digital analysis of a fixed point in the video recordings).

The time at which a calf completed its transition to either a lying or a standing position was recorded by a single observer.

2.3. Statistical analyses

2.3.1. Testing to ascertain if the automated and manual methods differ significantly

In order to determine the magnitude of any variation between the two methodologies, both datasets were directly contrasted. As explicitly

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