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Technical Note

Distinguishing Cattle Foraging Activities Using an Accelerometry-Based Activity Monitor

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Abstract

Various sensors and analytic tools have been developed to assist with the collection and analysis of data regarding the activities of animals at pasture. We tested an accelerometry-based activity monitor, the Kenz Lifecorder EX (LCEX; Suzuken Co Ltd, Nagoya, Japan), to differentiate between foraging and other activities of beef cows in a steeply sloping pasture. Logistic regression (LR) and linear discriminant analysis (LDA), two of the most widely used techniques for distinguishing animal activities based on sensing device information, were employed in the analysis. An LCEX device was worn on a collar by each of four cattle over the course of 4 d, during which time the activity (foraging, resting, ruminating, walking, and grooming) of each cow was recorded by trained observers at 1-min intervals for a total of 15 h. LR and LDA were applied to the LCEX and observer data to distinguish between foraging and other activities. Overall, a more accurate measure was obtained by LDA (90.6% to 94.6% correct discrimination among cows) than by LR (80.8% to 91.8% correct discrimination). The threshold LCEX value for distinguishing between foraging and other activities varied among cows, and the correct discrimination rate for the pooled data set was 92.4% for LDA and 85.6% for LR. Based on individual cow LDA, the time spent foraging averaged between 443 and 475 $\text{min} \cdot \text{d}^{-1}$. Our results indicated that LCEX can be used to identify the foraging activity of cattle.

Key Words: activity monitor, cow, grazing behavior, grazing management, linear discriminant analysis, logistic regression

INTRODUCTION

The development of simple, cost-effective tools for the temporal monitoring of cattle on pasture or rangeland could benefit both producers and researchers. Global positioning systems (GPSs) have increasingly been used to monitor spatial distribution and track routes (Ganskopp et al. 2000; Ganskopp 2001; Barbari et al. 2006) and are often combined with sensing devices to monitor animal activities, especially grazing behavior. Information on grazing behavior can be acquired from these devices by measuring the electrical resistance of jaw opening (Penning 1983; Matsui and Okubo 1991; Rutter 2000) or by pendulum pedometers fitted around the neck (Phillips and Denne 1988; Umemura et al. 2009); tilt sensors attached to a commercial GPS tracking collar (Ganskopp 2001); devices that record the sounds of bites and chewing in grazing (Ungar and Rutter 2006); and accelerometers fitted on the jaw or neck (Wark et al. 2007; Watanabe et al. 2008; Moreau et al. 2009). However, most of these devices cannot be used by farmers because they are only capable of taking measurements for a few days, due to their high energy consumption, or because they are expensive and require extensive experience to correctly attach them to animals (Ungar and Rutter 2006). Moreover, the data obtained by such sensing devices are complex, and the classification of grazing behavior requires custom software, such as the "Graze" program (Rutter 2000).

Recently, simple accelerometry-based activity monitors have been developed for studies of human health (Kumahara et al. 2004; Ayabe et al. 2006; McClain et al. 2007). Although these devices convert raw accelerometer data into activity levels using proprietary criteria, that data can be accessed and analyzed independently for animal activity studies. Ueda et al. (2011) developed a simple method for identifying the foraging activity of dairy cows in flatland pasture using the Kenz Lifecorder EX (LCEX; Suzuken Co Ltd, Nagoya, Japan) and a manually identified threshold value. The LCEX has recently been developed into a commercially available tool for human health management and research at a relatively low price (approximately 430 US dollars per unit). However, to further develop cow activity monitoring using the device, we tested the ability of the LCEX system to monitor activity of beef cattle in a steeply sloping pasture, because most of the grazed pasture in Japan is located in mountainous or hilly terrain. The analytic methods used to distinguish foraging activity were logistic regression (LR) and linear discriminant

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analysis (LDA; Fisher 1936), which have been used for animal activity classification in previous studies (Schleisner et al. 1999; Ungar et al. 2011).

MATERIALS AND METHODS

Kenz Lifecorder EX

The LCEX (weight, 60 g; width, 72.5 mm; height, 41.5 mm; thickness, 27.5 mm) is a single-axis accelerometer that measures vertical acceleration at a rate of 32 samples per second. The LCEX records at 4-s intervals a step count and an intensity of movement at 11 scaled magnitudes: 0 (none), 0.5 (subtle) and 1 to 9 (1, light; 9, vigorous). The internal memory can store 5 wk of data, and the device can operate for 14 wk using a CR2032 lithium ion battery. The LCEX is usually worn by people on a belt at waist level. According to Kumahara et al. (2004) and McClain et al. (2007), an activity level of 0 (AL_0) indicates that the acceleration values are always less than the minimum sensitivity of the device (0.06 G) during the 4-s sampling intervals. AL_0.5 indicates that acceleration values greater than 0.06 G occurred at one or two pulses during the 4-s sampling interval. When the sensor detects three or more such acceleration pulses in the 4-s interval, the activity is categorized from AL_1 to AL_9 according to the three largest acceleration values in the range 0.06 G to 1.94 G. Using the dataset of the activity level in 4-s intervals, human energy expenditure can also be estimated. The collected data can easily be downloaded onto a computer for analysis using Kenz Physical Activity Analysis software version 1.0 (Suzuken Co Ltd, Nagoya, Japan).

Testing LCEX on Grazing Cattle

The study was conducted in a mixed sown pasture of orchardgrass (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* Schreb.), meadow fescue (*Festuca pratensis* Huds.), Kentucky bluegrass (*Poa pratensis* L.), timothy (*Phleum pratense* L.), redtop (*Agrostis alba* L.), and white clover (*Trifolium repens* L.). The paddock (0.85 ha) was located on a northeast-facing slope ranging from 115 m to 135 m above sea level over a distance of 170 m (average slope 7.9°) at the National Agriculture and Food Research Organization Hokkaido Agricultural Research Center (lat 42°59′N, long 141°24′E; Fig. S1; available online at http://dx.doi.org/10.2111/REM-D-11-00027.s1). In this paddock, 20 breeding Japanese Black cows and their five calves were stocked for 4 d from 1000 hours 14 June 2010 to 1000 hours 18 June 2010. Six cows (cow 1: 596 kg, 16 yr old; cow 36: 516 kg, 6 yr old; cow 50: 588 kg, 4 yr old; cow 54: 458 kg, 3 yr old; cow 62: 407 kg, 2 yr old; and cow 63: 395 kg, 2 yr old) were selected from the 20 cows based on balancing by age and body weight. Three cows (cows 36, 54, and 62) had one calf younger than 1 mo old. Each cow was fitted with a collar to which was attached a small fabric bag containing an LCEX. The LCEX was wrapped in a waterproof vinyl bag (115 mm×90 mm×28 mm) and placed within the small fabric bag (Fig. S2; available online at http://dx.doi.org/10.2111/REM-D-11-00027.s1).

Four of the six cows wearing the LCEX were each observed for a total of 15 h during a 3-d period in June 2010: 3 h (1100–1200 hours and 1500–1700 hours) on 16 June 16; 9 h (0500–0800 hours, 0900–1200 hours, and 1400–1700 hours) on 17 June; and 3 h (0500–0800 hours) on 18 June. The animals were monitored by three trained observers, and their posture (standing or lying) and activity (foraging, ruminating, resting, walking, grooming, or drinking) were recorded every minute using instantaneous scan sampling. Both clocks of the LCEX and stopwatches used by observers were synchronized with a computer clock before the trial. After the 3-d observation, the stopwatches accumulated a clock drift of less than 5 s relative to the LCEX devices.

With the exception of day 3, when 26.6 mm of rain fell, the weather was clear. The mean air temperature was 18.1°C, and the maximum and minimum temperatures were 24.5°C and 15.2°C, respectively. The sunrise, meridian passage, and sunset times (GMT+9) at the experimental paddock were 0352 hours, 1135 hours, and 1918 hours, respectively.

Data Treatment and Statistical Analysis

The data collected from the LCEX devices were processed and analyzed both for each animal and for the pooled data using R statistical software, version 2.12.1 (R Development Core Team 2010). The LCEX data were summed every minute to match the 1-min interval used for field observations. To distinguish between foraging and all other recorded activities, the 1-min interval data from LCEX and the observations were subjected to LR and LDA.

To validate the accuracy of the LR and LDA functions, a bootstrap procedure with 10 000 iterations was applied based on an independent test data set, as described by Watanabe et al. (2008). At each iteration, the data were randomly divided into a training subset for model development and a test subset for validation at a proportion of two to one, respectively. Next, the training subset data were used to develop the LR and LDA functions. Finally, the classification accuracies of the foraging activities in the test subset were calculated using these functions.

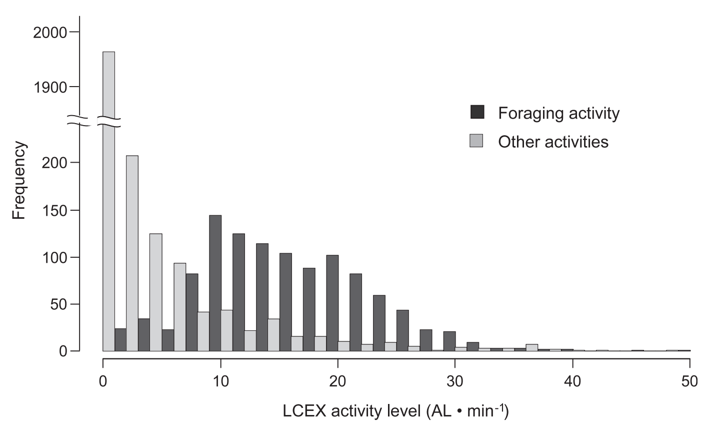

Figure 1. Distributions of the LCEX activity levels (AL · min^{-1}) for foraging activity and other activities for four cows over 15 h of behavioral observation from 1000 hours 14 June 2010 to 1000 hours 18 June 2010 in an experimental paddock (0.85 ha) at Hokkaido, Japan.

RESULTS

All LCEX devices successfully acquired the scheduled records during the 4-d measurement periods. From 15 h of behavioral observation, 906 min of data were obtained for each cow, providing a total of 3 624 min of data. The overall mean activity level (AL · min^{-1}) values and standard deviations (SD) were 15.1 ± 7.2 for foraging and 2.7 ± 5.9 for other activities (Fig. 1 and Table S1; available online at http://dx.doi.org/10.2111/REM-D-11-00027.s2). Among cows, the mean activity level ranged from 13.9 to 16.4 AL · min^{-1} for foraging and from 1.4 to 4.5 AL · min^{-1} for other activities.

Histograms of the percent correct discrimination scores for foraging in 10 000 bootstrap replicates using the LR and LDA functions are shown in Figure 2. The threshold values (above which activity is classified as foraging and below which activity is classified as other activities) for each cow based on LR were larger (8.5 to 16.6 AL · min^{-1}) than those based on LDA (7.8 to 10.4 AL · min^{-1}; Table S1). For the pooled data set, the mean LR- and LDA-based threshold values (± SD) were 10.8 ± 0.2 AL · min^{-1} and 8.9 ± 0.1 AL · min^{-1}, respectively. Overall, LDA yielded higher correct discrimination for all cows (90.6% to 94.6%) than LR (80.8% to 91.8%). Similarly, correct discriminations for LDA and LR for the pooled data set were 92.4% and 85.6%, respectively. The proportions of true nonforaging observations that were misclassified as foraging activity in the analysis of the pooled data set using LDA were 6.8% for resting and 0.8% for ruminating.

The mean threshold activity level value derived by LDA was applied over the entire period of the LCEX data in order to obtain the hourly pattern of foraging activity for each cow (Fig. 3). Each cow primarily grazed during the daylight period, which started at sunrise and ended at sunset. The primary periods in which the cows were engaged in foraging activity were after sunrise (0400 hours to 0500 hours), before noon (1000 hours to 1200 hours), and before sunset (1600 hours to 2000 hours). Over the course of a 24-h period, the cows spent an average of 443 to 475 min (30.7% to 33.0% of the time) foraging (Table S2; available online at http://dx.doi.org/10.2111/REM-D-11-00027.s2).

DISCUSSION

The present study confirmed that the LCEX device can be used to determine foraging activity in beef cows at pasture. This device was originally developed for research on human health and human health management (Kumahara et al. 2004; McClain et al. 2007). However, in a recent test on dairy cows using LDA, Ueda et al. (2011) showed that foraging activity can be identified with a misclassification rate of less than 5.5% using AL_1 as a threshold value based on the 4-s data set. This corresponds to an activity level of 15 on a per-minute basis. Our analyses using LDA based on the 4-s values summed over 1-min intervals yielded a similar activity level for foraging activity of 15.1 ± 7.2 AL · min^{-1} for the pooled data set. This might be thought that LCEX can be used to monitor foraging and other activities of grazing beef cows on a steep topography. Further study is needed to test the effect of topography on the threshold values.

Threshold values tended to be higher for LR than LDA. LR is a generalized linear regression using a logistic function that makes the logit transform of binary data, which in this case separated foraging from other activities. This may have led to the higher threshold values for LR than LDA. Several studies have indicated that discriminant analysis is a useful method for

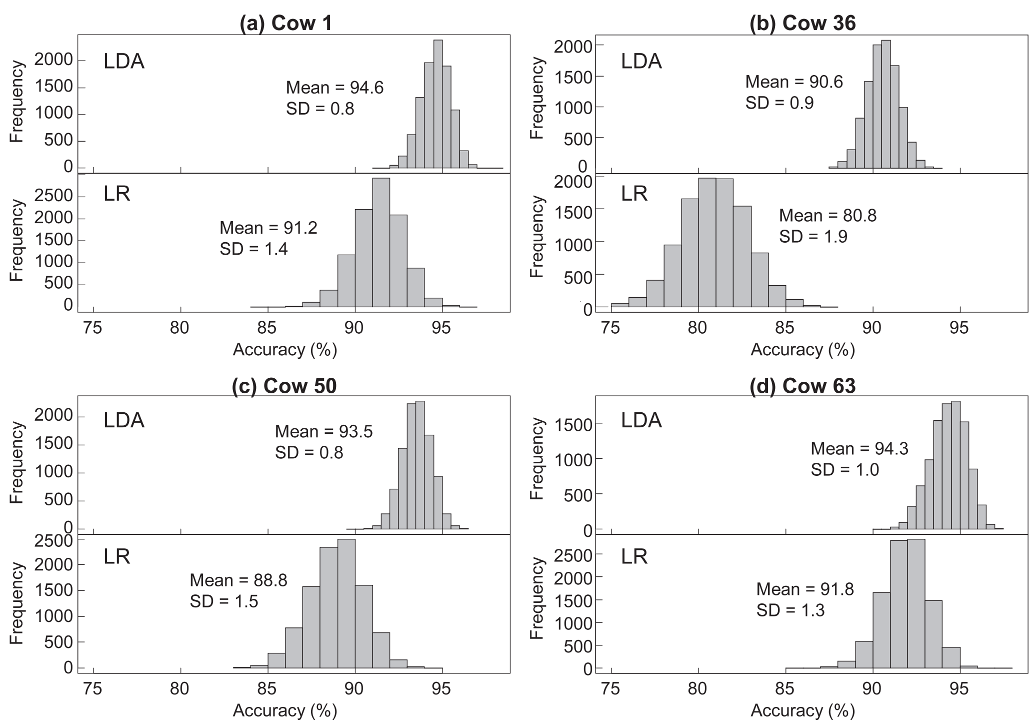

Figure 2. Density distributions of the percentage of correct classification of foraging activity based on bootstrapping 10 000 times using logistic regression (LR) and linear discriminant analysis (LDA) applied to LCEX data obtained from cattle at Hokkaido, Japan in June 2010.

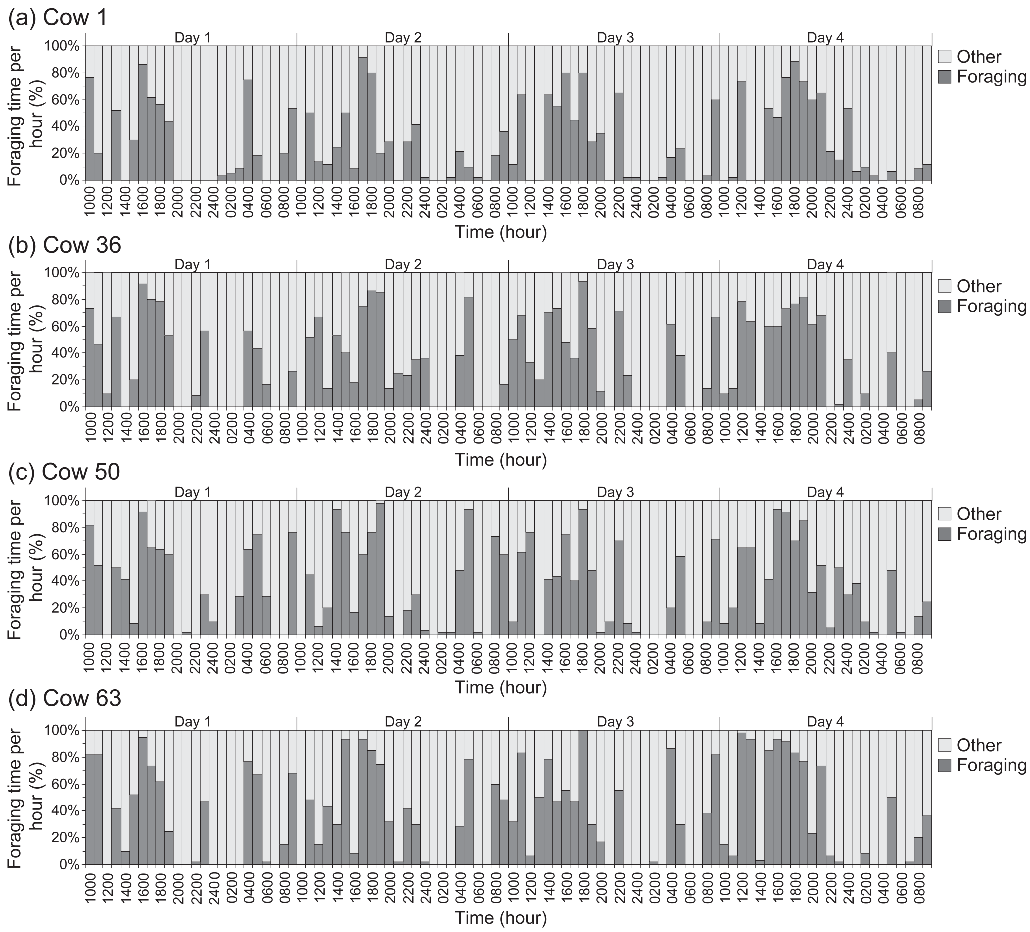

Figure 3. Hourly distributions of cow foraging activity derived by linear discriminant analysis (LDA) from LCEX data during a 4-d grazing experiment in June 2010 in an experimental paddock at Hokkaido, Japan.

identifying accelerometer variables that classify series of successive cow jaw movements into rumination and foraging behaviors (Schleisner et al. 1999; Watanabe et al. 2008). In the present study, we found an improvement in the discrimination scores when they were based on discriminant analysis (90.6% to 94.6%) as opposed to LR (80.8% to 91.8%; Fig. 2).

The LCEX data in conjunction with LDA for each cow were used to generate the activity timelines of the cows in the pasture and allowed the calculation of the hourly and daily foraging time (Fig. 3). The diurnal pattern that emerged was consistent with previous reports that cows graze more and are more active during daylight hours than at night (Ueda et al. 2011). There are two major grazing periods during the day: a long afternoon period and a shorter morning period (Schlecht et al. 2004; Lin et al. 2011).

The main advantages of the LCEX system in behavioral research are its low weight and low price. Several studies have reported that simultaneously attaching different sensing devices to an animal has certain disadvantages because weight of the equipment may cause the animal to tire more quickly and thereby influence its activity (Rutter et al. 1997). Cuthill (1991) suggested that sensing devices should weigh less than 5% of the animal's body weight. Blanc and Brelurut (1996) reported that a satellite-tracking collar weighing 3.5% of body weight significantly decreased the grazing activity of red deer (*Cervus elaphus*) and disturbed other behavioral activities. In contrast, Hulbert et al. (1998) found that a collar carrying a lightweight GPS weighing only 2.2% of body weight had no influence on the behavior of 16 Scottish Blackface ewes. Clearly, an automatic data logger should weigh as little as possible and should not restrict the animal's freedom of movement. In our study, the collar and device amounted to no more than 0.4% of the animal's body weight, so deployment together with an additional sensor such as a GPS collar should not present a problem.

IMPLICATIONS

The Kenz Lifecorder EX accelerometry-based activity monitor can be used to distinguish between foraging and other activities of grazing beef cows on a hilly pasture. Our results indicate that LDA yields better discrimination accuracy than LR when using minute-based data, which is a time interval suitable for integrated use with GPS location information. The combination of the activity timeline and GPS tracking data can determine the spatio-temporal distribution of cow foraging activity on pasture or rangeland.

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