Technical note: Monitoring grazing bites and walking activity with pedometers

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ABSTRACT

Three types of pedometers installed on loosely fitted neck collars were investigated to determine the accuracy with which the devices measured the number of grazing bites performed by cows. The pedometer memory stored the summed number of bites over 1-h intervals for up to 10 d, and the battery had a life of more than 3 mo. The values recorded by the pedometers were linearly related to the number of bites measured by visual observation and were unaffected by rumination. The correlation coefficients between the pedometer values and the number of bites were all >0.9. Circadian and day-to-day variations in the number of grazing bites were obtained by all 3 pedometers. The regression coefficients differed among the pedometers. The pedometers also responded to the occurrence of walking steps. The values recorded by the pedometers were linearly related to the observed number of walking steps. The correlation coefficients between the pedometer values and the number of steps were all >0.9. Although the number of walking steps affected the number of grazing bites, the number of bites greatly exceeded the number of walking steps. One type of pedometer, equipped with a 2-dimensional accelerometer, was used to analyze both grazing and walking behaviors. The back–forth and right–left movements of the pedometer had similar values during walking, whereas the values of the back–forth movements were greater during grazing. I conclude that pedometers can be used to measure the number of grazing bites but that this technique requires calibration to relate the pedometer values to the number of grazing bites. Observations of the back–forth and right–left movements of pedometers on neck collars will aid in distinguishing the grazing and walking behaviors of cows.

Key words: pedometer, grazing, walking

Technical Note

Monitoring the grazing behavior of cattle contributes improved information on the management of grazing

livestock (Holmes and Wilson, 1984), on feeding activities (DeVries and Keyserlingk, 2005), on the material cycle of pastures (Betteridge et al., 2010), and on the effects of ectoparasites (Boland et al., 2008). Because of the broad range of applications served by the monitoring of grazing behavior, the development of an effective and low-cost monitoring system will be useful. We have previously shown that an accelerometer attached to a neck collar can estimate the number of bites performed by grazing cows (Umemura et al., 2009). In Experiment (**Exp.**) 1 of this study, we examined the accuracy with which pedometers on loosely fitted collars can be used to measure the number of grazing bites and the number of walking steps. In Exp. 2, axial movements in the back–forth and right–left directions were recorded with modified pedometers to monitor both walking and grazing behavior.

In Exp. 1, values were obtained with 3 different types of pedometers. The first pedometer was developed by Omron Co. (HJ-7101T, Kyoto, Japan; weight 37 g, **O** pedometer). The memory stored the number of bites over 1-h intervals for up to 10 d. The lifespan of the battery (3.0 V, CR2032) was more than 6 mo. The second pedometer was developed by Panasonic Electric Works Co. Ltd. (EW4800, Kadoma, Osaka, Japan; weight 31 g, **P** pedometer). The memory stored the number of bites over 1-d intervals for up to 6 mo. The lifespan of the battery (CR2032) was more than 2 mo. Both the O and P pedometers had 2-axis acceleration sensors. The third pedometer was developed by Tanita Co. (FB-720, Tokyo, Japan; weight 23 g, **T** pedometer). The memory stored the number of bites over 1-d intervals for up to 7 d. The lifespan of the battery (CR2032) was more than 3 mo. This pedometer had a 3-axis sensor. All 3 pedometers were housed in water-tight and dust-tight polycarbonate plastic boxes made by Ensto Oy (DP-CP080806T, Porvoo, Finland; 80 × 82 × 56 mm, 130 g; Figure 1, left). The units were installed on loosely fitted neck collars for use in cows (Figure 1, right).

The accuracy with which each pedometer measured the number of grazing bites was evaluated in 3 multiparous lactating Holstein cows (683 ± 38 kg of BW) on a 0.2-ha sown pasture consisting of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens*

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Figure 1. Pedometers contained in waterproof housings for use with a neck collar (left). These pedometers counted head-down jaw movements during grazing (right). The counters did not count jaw movements occurring during rumination; these movements occur only when the head is raised. Color version available in the online PDF.

L.). The herbage mass was measured as available DM above a 5-cm stubble height using a rising plate meter (Reeves et al., 1996) before the observations. The rising plate meter was calibrated using five 0.25-m² quadrats. The average mass was 198 g/m². Plant length was measured at 30 points and the average was 26.7 cm. During grazing, the plastic box on the collar was in contact with the cow's jaw when the cow's head was lowered. The observations were performed after morning milking. Starting at the beginning of the observations, the cows wore the collars with the attached pedometers. The number of bites was obtained from direct visual observations of 5 grazing bouts per cow. A cow would typically be observed once or twice daily. This procedure was performed with each pedometer. The number of bites during a single grazing bout varied from 19 to 774. The lengths of grazing bouts observed were 15 to 700 s. The numbers shown by the pedometers were recorded at the beginning and end of each bout. The beginning number was subtracted from the end number to calculate the pedometer values.

No differences in values between cows were observed. The values shown by the 3 pedometers were linearly related to the number of bites recorded by visual observation. The regression coefficients differed among the pedometers. The regression equations and correlation coefficients were as follows: O pedometer, $y = 1.5x - 7.3$, $r = 0.99$, $n = 15$ ($P < 0.01$); P pedometer, $y = 1.6x - 7.9$, $r = 0.96$, $n = 15$ ($P < 0.01$); T pedometer, $y = 1.8x - 7.8$, $r = 0.98$, $n = 15$ ($P < 0.01$), where y = pedometer values and x = number of bites. The regression coefficients were smaller than those obtained

in a previous report (Umemura et al., 2009). The probable explanation for this difference is that because lightweight objects are easy to move due to the law of inertia, small-amplitude vibrations during grazing affected the boxes containing the pedometers. The weight of the box used for the pedometers in the present study was approximately 160 g, whereas the box used in the previous study weighed approximately 350 g.

Rumination behaviors that occurred after the observation of each grazing bout were observed for 3 min in the same cows. The mean number of jaw movements observed during the rumination periods was 59.6 ± 1.6 times/min (mean $\pm$ SD). On average, the values obtained by the pedometers during the rumination periods were 0.75% of the number of jaw movements. During the rumination, the plastic box housed the pedometer was not in contact with the jaw while the head was raised.

The values shown by each pedometer during walking were evaluated in the same cows. Steps were counted by visual observation for 4 walking bouts per cow on different days. One walking bout, consisting of a sequence of walking steps, ranged from 13 to 577 steps. These bouts were measured while the cows were moved from their milking barn to the pasture. Each cow was observed once daily, and the lengths of 10 strides were measured twice for each cow.

The values shown by the 3 pedometers were linearly related to the number of walking steps determined by visual observation. The regression coefficients differed among the 3 types of pedometers. The regression equations were as follows: O pedometer, $y = 1.3x + 11$, $r =$

0.99, $n = 12$ ($P < 0.01$); P pedometer, $y = 1.1x + 75$, $r = 0.94$, $n = 12$ ($P < 0.01$); T pedometer, $y = 1.1x - 15$, $r = 0.98$, $n = 12$ ($P < 0.01$), where y = pedometer values and x = number of steps. The slopes of these regression equations were slightly greater than 1.0. The explanation for this could be that pedometers were developed not to monitor the quadrupedal locomotion of cows but to monitor human bipedal locomotion. Although the walking pattern of large quadrupedal mammals may appear to be equivalent to the human walking pattern, the quadrupedal walking pattern actually resembles the pattern produced by 2 men walking out of phase, one behind the other and one-quarter cycle out of step (Alexander, 1987). This pattern includes more swings than does human walking.

The maximum number of bites during grazing can reach 50,000 bites/d (Phillips, 2002). The distance traveled during grazing averages approximately 4 km/d (Hafez and Bouissou, 1975), and the length of a step was 0.76 ± 0.07 m (mean $\pm$ SD) for the cows in the current study. However, it is clear that the pedometer values for the number of bites included the number of steps recorded, and these results show that the number of walking steps is much less than the number of grazing bites and does not affect the estimation of grazing behavior in most cases.

The O pedometer's 2 acceleration sensors were constructed from 2 cantilevers crossing at a right angle.

In Exp. 2, the acceleration sensors were inactivated one by one. The values of the back-forth and right-left movements were recorded by these modified pedometers during grazing and walking. The procedure was the same as that used in Exp. 1. Seven multiparous, lactating Holstein cows were observed. The numbers of bites and steps were counted by visual observation for 2 bouts per cow on different days. For both behaviors, the bouts in which both behaviors occurred fewer than 20 times were omitted from the analysis. The cows were observed once daily.

The back-forth and right-left movements of the pedometers on the collars coincided during grazing and walking behavior. When the cow's head was lowered during grazing, the regression coefficient for the back-forth movement was greater than the regression coefficient for the right-left movement because the pedometer was in contact with the jaw. When the cow walked, the decrease in the regression coefficient for the back-forth movement was greater than the decrease in the regression coefficient for the right-left movement (Figure 2).

I conclude that pedometers can be used to measure the number of grazing bites and to determine the circadian and day-to-day variations in the number of grazing bites. This technique requires calibration because differences in regression coefficients between the number of grazing bites and the pedometer values are

Figure 2. Acceleration sensor values for back-forth and right-left movements during grazing and walking. The number of back-forth movements exceeded the number of right-left movements during grazing.

expected among different models of pedometers. Moreover, pedometers can provide low-cost measurements of eating behavior indoors. This approach is feasible whether the cow is free or in a stanchion stall because the counter is in contact with the jaw when the head is lowered during eating. Ueda et al. (2011) have argued that information about grazing times (min/d) can be used to estimate herbage intake of grazing cattle. Because biting rates have been found to vary (Hodgson and Wilkinson, 1967; Phillips, 2002), the number of grazing bites may allow a better estimation of forage intake during grazing. It is probable that measurements of the number of grazing bites are accurate because differences in biting rates have been found to vary among grazing bouts and seasons (Phillips, 2002) and with the age of the cattle (Hodgson and Wilkinson, 1967).

The pedometer values were also linearly related to the number of walking steps determined by visual observation. To monitor walking steps, pedometers or accelerometers have been attached to the lateral side of the leg, above the fetlock (Kiddy, 1977; Lehrer et al., 1992; Chapinal et al., 2011). The results of the current study indicate that observations of acceleration obtained from the collars could be used to measure the number of walking steps, although the acceleration will need to be separated from the number of grazing bites. In Exp. 2, the back-forth movements decreased when cows were walking. If this decrease is monitored with equipment mounted on a collar, we could potentially distinguish grazing and walking. Recording both back-forth and right-left movements can represent a possible method of simultaneously measuring the number of grazing bites and the number of walking steps.

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