Peri-estrus activity and mounting behavior and its application to estrus detection in Hanwoo (Korea Native Cattle)

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한우의 발정기 활동량과 승가행동을 이용한 발정탐지

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Abstract

This study was conducted to investigate the change in activity and mounting behavior in Hanwoo (Korean Native Cattle) during the peri-estrus period and its application to estrus detection. Each cow was fitted with a neck-collar accelerometer device, which measured the location and acceleration of cow movements and recorded the number of instances of mounting behavior by the altitude data. The data were obtained from 8 cows and analyzed in three periods (24-, 6-, and 2-h periods). As result, Hanwoo cows show a clear increase in activity ($p < 0.0001$) and mounting behavior ($p < 0.01$) as estrus approaches. Activity was the most reliable parameter for identifying estrus of cows by stepwise discriminant analysis, but activity alone is not enough to detect estrus. Some cows were only detected as being in estrus by observing mounting behavior data. Thus, the number of mounting behavior can be used as an assisting parameter to detect cows in estrus. One of the most important results was that the data made over 2-h periods was more efficient at detecting estrus than over 24- and 6-h periods. We suggest that a combination of activity and mounting behavior may improve estrus detection efficiency in Hanwoo. Further research is necessary to validate the findings on a larger sample size.

1. Introduction

Accurate and efficient detection of estrus is essential for the successful reproductive performance in cattle herds. Visual observation for estrus detection is not practical, especially for large herds, because it is required additional labor from skilled stock persons. This has prompted the development of automatic estrus detection techniques that characterize estrus behavior or measure endocrine hormones. However, there remain several challenges in estrus detection on farms. For instance, studies have shown an extreme decline in the intensity and duration of estrus signs. Standing to be mounted, which is recognized as the primary sign of estrus, has recently reduced from 80% to 50% and the average duration of standing has decreased from 15 to <8 h, and sometimes only 4 h [1,2]. Furthermore, secondary behavioral signs of estrus have exhibited steady declines. There is considerable evidence that modern dairy cows selected for increased milk yields exhibit decreased fertility [3]. In addition, cows kept indoors on concrete expressed fewer behavioral signs than those housed on pasture [4]. Detection of estrus is complicated by a variety of factors.

In recent years, activity monitoring systems have been widely commercialized, such as pedometers that record the number of steps and 3-axes accelerometers that record cow movements. However, activity monitoring systems alone are not enough to detect estrus. Thus, recent research has attempted to combine the features of multiple estrus behaviors for the accurate identification of estrus. Therefore, the objective of this study was to investigate the peri-estrus activity and mounting behavior in Hanwoo and utilize the obtained insights for estrus detection.

2. Materials and Methods

2.1 Animals, Housing, and Management

Our experiment was conducted from June 2021 to February 2022 at the Kangwon National University farm (Chuncheon, Korea). A total of 20 Hanwoo cows (28.8 ± 10.4 months of age) were housed in freestall pens (2 or 3 cows/pen; 4.0 × 7.5 m2) on concrete floors, bedded sawdust, and dried manure solids. They were synchronized for estrus by the administration of 25 mg of prostaglandin F2α (Lutalyse®, Zoetis, Belgium) at the start of the study and again 11 days later if they did not observed estrus. The cows were fed a concentrated diet in accordance with the Korean Feeding Standards for Hanwoo. Rice straw (1 kg) was fed twice daily at 08:00 ± 1 and 16:00 ± 1 h. Water was available ad libitum. All cows were visually checked for signs of disease or injuries. No occurrences of disease or injury were registered during the experiment period.

2.2 Estrus Confirmation

Visual observations were carried out for estrus over 30 min thrice (at 09:00, 15:00, and 21:00 h) daily by a single observer. The day when estrus was identified by visual observation was defined as estrus (day of estrus = d0) and compared with 3 days before (d−3, d−2, and d−1) and 2 days after (d+1 and d+2).

2.3 Sensors

Each cow was fitted with a biotelemetry device attached to a neck collar. This device enabled the automated measurement of location and acceleration (x-, y-, and z-axis) of cow movements. To count the number of mounting behavior, the altitude data were obtained from the z-axis plus altimeter accelerator. All data were wirelessly transmitted to the receiver based on an ultra-wideband (UWB) installed in the barn using 16 anchors.

2.4 Statistical Analysis

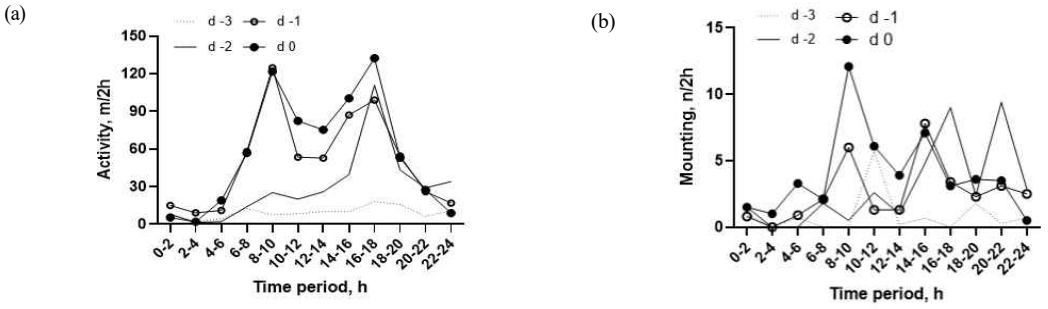
The data were statistically analyzed using the SAS GLM procedure (SAS Inst., Inc., Cary, NC, USA) and Tukey's post hoc test. Furthermore, a stepwise procedure was used to select the predictor for discriminant analysis.

3. Results

Only eight cows were detected as being in estrus through visual observation. The profiles (mean ± S.D.) of activity and mounting behavior during the peri-estrus period are presented in Table 1. The data recorded by the biotelemetry device were analyzed in three periods (24-, 6-, and 2-h periods). There was a significant difference in activity per 24-h ($p < 0.01$), whereas mounting behavior did not differ ($p > 0.05$). However, there were significant differences in both activity and mounting behavior when the data were recorded over 6- and 2-h periods. The average activity values were 124.6 ± 70.1 m (range from 0 to 578.1 m, $p < 0.001$) in 6-h periods and 41.5 ± 23.4 m (range from 0 to 304.2 m, $p < 0.0001$) in 2-h intervals. The average number of mounting behavior was 7.9 ± 7.2 (range from 0 to 63, $p < 0.05$) in 6-h periods and 3.0 ±

Table 1. The profiles (mean ± S.D.) of activity and mounting behavior during the peri-estrus period in Hanwoo cows submitted to estrus synchronization and monitored with sensing collars.

Parameter*	Day						*p*-value
	-3	-2	-1	0	1	2	
Activity, m							
24-h periods	114.4 ± 155.5^{b}	353.8 ± 173.3^{ab}	608.2 ± 199.7^{a}	684.9 ± 264.4^{a}	597.6 ± 248.4^{a}	536.0 ± 189.5^{a}	<0.001
6-h periods	28.6 ± 38.9^{b}	88.5 ± 46.3^{ab}	152.0 ± 53.4^{a}	171.2 ± 70.7^{a}	149.4 ± 66.4^{a}	134.0 ± 50.7^{a}	<0.001
2-h periods	9.5 ± 13.0^{c}	29.5 ± 15.4^{bc}	50.7 ± 17.8^{a}	57.1 ± 23.6^{a}	49.8 ± 22.1^{a}	44.7 ± 16.9^{ab}	<0.0001
Mounting, no.							
24-h periods	11.0 ± 17.7	35.8 ± 40.7	31.3 ± 25.6	47.9 ± 34.2	21.5 ± 19.5	36.8 ± 21.7	0.22
6-h periods	2.8 ± 4.4^{b}	8.9 ± 10.2^{ab}	7.8 ± 6.3^{ab}	12.0 ± 8.6^{ab}	5.4 ± 4.9^{ab}	9.2 ± 5.4^{ab}	<0.05
2-h periods	0.9 ± 1.5^{c}	3.0 ± 3.4^{ab}	2.6 ± 2.1^{ab}	4.0 ± 2.9^{a}	1.8 ± 1.6^{ab}	3.1 ± 1.8^{ab}	<0.01



[Figure 2] Distribution of cows' activity and mounting behavior during a 24-h period (d0: day of estrus).

5.0 (range from 0 to 40, $p < 0.01$) in 2-h periods. The parity did not affect the activity and mounting behavior of cows during the peri-estrus period ($p > 0.05$). In the result of stepwise discriminant analysis, activity was selected as the best predictor (58.3%) for estrus detection in Hanwoo cows.

3.1 Activity

The average activity of Hanwoo cows was 9.5 ± 13.0 m/2-h periods on d−3. It was significantly increased by 209% (29.5 ± 15.4 m/2-h periods) on d−2 and increased 432% (50.7 ± 17.8 m/2-h periods) on d−1 ($p < 0.05$). On d0, the cows showed the peak of activity (57.1 ± 23.6 m/2-h periods), and then activity decreased by only 16.8% on d+1 and d+2 ($p > 0.05$).

The circadian rhythm of activity was bimodal, with two peak phases occurring between 08:00 and 10:00 h and between 16:00 and 18:00 h (Fig. 2a). On d−2, the activity value started to increase remarkably in the afternoon, with a peak phase (89.1 ± 76.3 m/2-h periods) and then reached a much higher level on d−1 and d0. Minimum activity occurred at 10.0 ± 14.5 m/2-h periods at night-time (22:00 – 04:00 h).

3.2 Mounting Behavior

The number of mounting behavior on d−2 was significantly increased by 225% (3.0 ± 3.4 events/2-h periods) compared with d−3 (0.9 ± 1.5 events/2-h periods). It attained the peak (4.0 ± 2.9 events/2-h periods) with an increase of 335% on d0 and immediately decreased the following day (1.8 ± 1.6 events/2-h periods).

The circadian rhythm of mounting behavior was different on all days of the pre-estrus period (Fig. 3b). Mounting behavior was observed more in the afternoon and at night-time on d−2 and d−1 and then showed a remarkable peak (12.1 ± 13.5 events/2-h periods) in the morning (0:800 – 10:00 h) on d0, although there was considerable variation among the individual cows.

4. Discussion

Activity measurement is the most common tool for estrus detection in cows. Many studies have reported that cows are significantly active on the day of estrus compared to on the other days, which is consistently seen in Hanwoo as well [5-7]. Our results confirmed that Hanwoo cows were 3 – 6 times as active during the peri-estrus period. Hanwoo cows showed a stepwise increase in activity from d−2 to d0. This can be interpreted as the cows starting to show sexual interest in their surroundings, accompanied by a restlessness in estrus. Thus, feed intake and rumination time temporarily decline during this period [8]. These characteristics can also be used as a tool for estrus detection, but they are difficult to record accurately. Activity after estrus did not immediately decrease and remained relatively high, contrary to previous findings [6]. Activity levels may be influenced by a variety of factors, such as genetics, parity, season, housing, and management [10], as well as milk production in dairy cows [9]. There was no significant difference in the interaction of parity and activity in our study. Valenza et al. [11] reported that activity measured using an accelerometer was not affected by parity or milk production. They also found that the mean period from onset of activity to ovulation was 28.7 h in dairy cattle. In the pedometer data, the average period between onset of pedometer estrus and ovulation was 29.3 ± 3.9 h, according to Roelofs et al. [7]. The timing of insemination relative to ovulation is one of the crucial factors for obtaining a good pregnancy rate. Future studies on factors that can influence the activity pattern and the periods related to ovulation are needed for accurate detection of estrus and proper timing of insemination to improve pregnancy outcomes in Hanwoo.

Mounting behavior is a secondary sign of estrus, which seems more efficient for estrus detection than standing behavior [12]. Cows that became pregnant were mounted more times than cows that did not become pregnant during estrus [13]. According to Pennington et al. [14],

mounting behavior mostly occurred in the unshaded dry lot and feed-manger areas. Furthermore, social interaction can influence the timing of this estrus behavior in herds; larger cows may initiate mounting and inhibit the mounting behavior of smaller cows [10]. Mounting behavior was more common in the afternoon and at night [15,16]. Phillips and Schofileld [16] demonstrated that mounting behavior was most common at 14:00 and 22:00 h, whereas attempted mounting appeared most often in the morning (05:00 and 10:30 h). By contrast, At-taras and Spah [17] reported that mounting behavior started most frequently in the morning. In our study, mounting behavior was observed most commonly in the afternoon and at night-time on d－2 and d－1, but there was a significant increase in the morning on the day of estrus. Thus, cows were mounted most often shortly before the day of estrus. Interestingly, estrus could be detected in some cows only by mounting behavior, not based on the activity data recorded by the accelerometer. Thus, mounting behavior is worthwhile to use as an assisting parameter for estrus detection, although there were variations among the individual cows.

In conclusion, the present study revealed that automated measurement of activity and mounting behavior could be used to identify estrus in Hanwoo. We suggest that a combination of activity and mounting behavior may increase estrus detection efficiency in Hanwoo. Also, the data recorded over 2-h periods was more efficient at detecting estrus than over 24- and 6-h periods. This finding can be used to enhance estrus detection on cattle farms, especially using machine learning techniques. Further research is necessary to validate the findings on a larger sample size.

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