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Automated Activity Monitoring of Estrus and Time of Ovulation

J. S. Stevenson

Summary

Detection of estrus can be facilitated by use of automated activity monitors that measure physical activity. Increased physical activity is largely correlated with estrus. Our objective was to determine when ovulation occurs relative to increased physical activity so we could recommend optimal timing of insemination to maximize conception rates in lactating dairy cows. Cows ($n = 65$) were fitted with pressure-sensitive rump-mounted transmitters (HeatWatch; **HW**) that are activated by a mounting herdmate to indicate standing estrus. The same cows also were fitted with neck-mounted activity monitors (Select Detect; **SD**). Additional cows ($n = 68$) were fitted with only the activity monitor. Beginning approximately 14.5 hours after the individual activity monitor on a cow reached a set threshold, transrectal ultrasonography was used to identify the ovarian preovulatory follicle. Repeated ovarian scans were performed every 3 hours until ovulation occurred or 36 hours after threshold was reached. Although average intervals to ovulation actually differed ($P < 0.05$) by only 1.5 h (27.2 ± 0.6 h for HW vs. 25.7 ± 0.4 h for SD), deviations between onsets differed by 2.0 ± 0.4 h (increased activity preceded time of standing to be mounted). Increased physical activity tended to increase before the first standing event and endured longer than the duration of estrus measured by HW. We concluded that the activity monitor was a reliable tool to detect estrus, and ovulation occurred at similar intervals from increased activity as from the first standing event associated with estrus.

Key words: estrus, ovulation, physical activity

Introduction

The latest version of electronic estrus-detection aids that appeared in the early part of this decade are neck-mounted activity tags containing a microprocessor and a 2- or 3-dimensional activity sensor. Monitoring activity has formed the basis for many pedometer or neck-mounted monitor systems marketed to the dairy industry because increased activity (motion, movement, walking, etc.) is correlated with estrus; activity increases up to 400% in 93% of estrous periods. One limitation of any system is the lesser activity associated with estrus for cows maintained in tie-stalls compared with free stalls or for cows in total confinement on concrete compared with dirt.

The newest generation of activity monitors employs an accelerometer device. Accelerometers are small (0.01×0.01 inch), reliable, and durable. Accelerometers were first developed for the military, aerospace, and automotive industries and have the capacity to detect motion in all three spatial planes. Now they are more popularly used in industrial, medical, and consumer devices with any number of applications. The accelerometer allows accurate measurement of cow movement. The activity tag monitors specific estrus-related movement and its intensity, resulting in estrus-detection accuracies of up to 90%. By 2010, the best-selling system in the world, with approximately 1 million estrus-detection tags sold, demonstrated that dairy farmers were willing to invest in technologies that provide a real solution to the problem of detection of estrus. These systems are effective management tools in the AI program because their use will increase estrus-detection rates, which will increase AI service rates and result in more pregnan-

cies. At least four patents have been issued describing some type of transponder system that is capable of detecting movement or motion and includes the ability to be interrogated in the milking parlor or send signals via wireless radiotelemetry.

Activity monitors periodically record data that are downloaded wirelessly to a base station or when the activity monitor is interrogated in the milking parlor, common feeding stations, or other high-traffic areas. The software operating on a personal computer downloads the activity data from the computer interface to the software for analysis. The activity analysis program algorithm examines within-cow activity to assist in detecting the amount of current activity as a function of the cow's most recent activity baseline. When current activity meets or exceeds a set threshold, the cow's identification is flagged by the software for further inspection and possible insemination.

Three previous studies have reported that time of ovulation was in reasonable agreement with the gold standard study, where ovulation occurred at 27.6 ± 5.4 h after the onset of estrus based on actual standing events associated with estrus. From the literature, it also seems likely that increased activity is largely correlated with the onset of standing estrus in studies where simultaneous measures were made.

The objective of this study was to determine when the ovulatory follicle disappears (ovulation) in lactating dairy cows enrolled in an AI program exposed to Select Detect activity monitor system and HeatWatch heat-detection systems.

Experimental Procedures

Lactating dairy cows enrolled in AI program were fitted with HeatWatch (**HW**; $n = 65$; Cow Chips LLC, Manalapan, NJ) heat-detection transmitters and Select Detect (**SD**; Select Sires Inc., Plain City, OH) accelerometer activity monitors. An additional 68 cows were fitted with only the SD monitors. Combining technologies allowed comparisons of the onset of estrus (first mount received per HW) with the timing of increased activity (first achieved threshold) as determined by an accelerometer activity system. When lactating dairy cows calved, they were fitted with SD accelerometer collars and HW transmitters to facilitate simultaneous collection of estrus and ovulation events. Cows enrolled in the study were set up for first AI beginning at 50 DIM by receiving either 25 mg prostaglandin F_{2a} (**PG**) or 100 μ g gonadotropin-releasing hormone (**GnRH**) i.m. that preceded the PG injection by 7 days to induce estrus. Cows identified in estrus either before or after first AI were studied.

When a cow was detected in estrus (at least 1 standing event), the hourly activity count reached a threshold (based on SD software), or both, transrectal ovarian scans were initiated beginning 14.5 ± 0.5 h later and continued every 3 h until the ovulatory follicle(s) disappeared or until 36 h had passed. At the initial scan, all follicular structures were mapped and sized with electronic calipers. The largest two follicles were monitored until either or both disappeared. A blood sample was collected at the first ovarian scan to measure concentrations of progesterone (< 1 ng/mL, which was indicative of true estrus).

Results and Discussion

Of 132 cows enrolled in the ovulation study, 117 (89%) had concentrations of progesterone < 1 ng/mL (mean = 0.11 ng/mL) and 15 (12%) had elevated concentrations of progesterone (mean = 5.35 ng/mL) at the first ovarian scan. Eleven of the 15 high-progesterone cows were

identified falsely by activity monitors (false positives). Of these 11 cows, 3 occurrences of 2 cows were detected together, and 1 occurrence of 5 cows was detected together within 1 to 5 h of each other. Of 117 low-progesterone cows, 88.6% ovulated (95.3% ovulated <36 h after detection by the activity monitor). Of the total data collected with the activity monitor, 59 of 106 ovulating cows also had HW-transmitter data.

Figure 1 illustrates the relative proportion of cows that ovulated at various intervals after detection by either standing to be mounted or by reaching the activity threshold. Although average intervals to ovulation actually differed ($P < 0.05$) by only 1.8 h (26.8 ± 0.7 h for HW vs. 25.0 ± 0.7 h for SD), actual deviations between onsets differed by 1.7 ± 0.4 h (increased activity was preceded by the first standing to be mounted event). Interval to ovulation detected by HW in our study and in an earlier report (27.6 h) was similar. For all 97 cows with activity monitors and verified ovulation, average interval to ovulation after reaching threshold was 25.7 ± 0.4 h. Based on 95% confidence intervals, time of ovulation after start of increased activity or first standing event consistently overlapped.

Mean interval to ovulation after the end of estrus or end of increased activity was greater ($P < 0.001$) for HW than for SD, respectively, whereas duration of estrus was greater ($P < 0.001$) for SD than HW (Table 1).

The close relationship between onset of standing-to-be-mounted and increased activity is illustrated in Figure 2. Large correlations were detected between estrual and ovulation traits as defined by HW and SD (Table 2). Near-perfect correlations between HW- and SD-defined onset and end of estrus were detected.

Detection of estrus is a key element in successful artificial insemination programs in dairy herds. Although timed insemination programs are popular and pregnancy outcomes are generally good, technologies available to detect estrus have proven effective in increasing heat-detection and service rates. The studied automated activity monitors closely identified onset of estrus compared with standing-to-be-mounted activity identified by HeatWatch. Time of ovulation relative to onset of estrus was similar between methods. Furthermore, with one activity accelerometer system, consistency of ovulation time relative to both onset and end of activity are very predictable. To maximize pregnancy outcome based on ovulation times identified with the SD system, insemination should occur between 12 and 18 hours after the first identified threshold of physical activity.

Table 1. Time of ovulation relative to estrus activity determined by automated activity accelerometers (Select Detect [SD]) or by standing to be mounted (stand) determined by HeatWatch [HW])

	SD	HW	HW	SD	HW	SD	HW
Item	Duration of activity ¹ , h	Duration of estrus, h	Standing events, no.	Ovulation after activity start ² , h	Ovulation after first stand, h	Ovulation after activity end ³ , h	Ovulation after last stand, h
Cows, no.	44	54	59	59	59	44	54
Mean	11.4 ± 0.9	5.7 ± 0.9	6.1 ± 1.2	25.0 ± 0.7	26.8 ± 0.7	13.4 ± 0.9	21.3 ± 0.9
95% CI	9.6 – 13.1	4.0 – 7.4	3.7 – 8.5	23.6 – 26.3	25.5 – 28.2	11.5 – 15.3	19.5 – 23.2

¹Duration above threshold.²Timed when activity increased above threshold.³Timed when activity decreased below threshold.**Table 2. Correlations of HeatWatch and Select Detect activity monitor defined estrual and ovulation traits**

Trait	Simple correlation	<i>P</i> -value
Onset of estrus to ovulation	0.722	<0.001
End of estrus to ovulation	0.341	=0.027
Onset of estrus	1.000	<0.001
End of estrus	0.999	<0.001
Duration of estrus	0.219	=0.193

REPRODUCTION

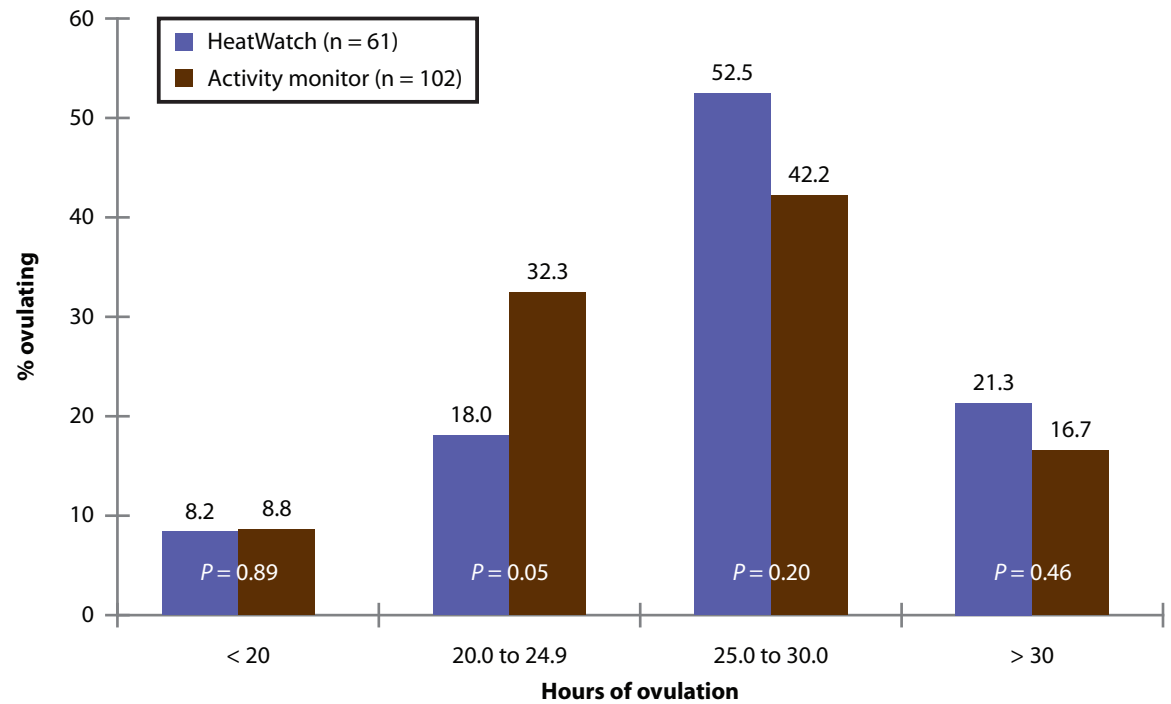


Figure 1. Proportion of cows that ovulated after onset of estrus (standing to be mounted as determined by HeatWatch) or after reaching threshold (based on Select Detect activity monitors).

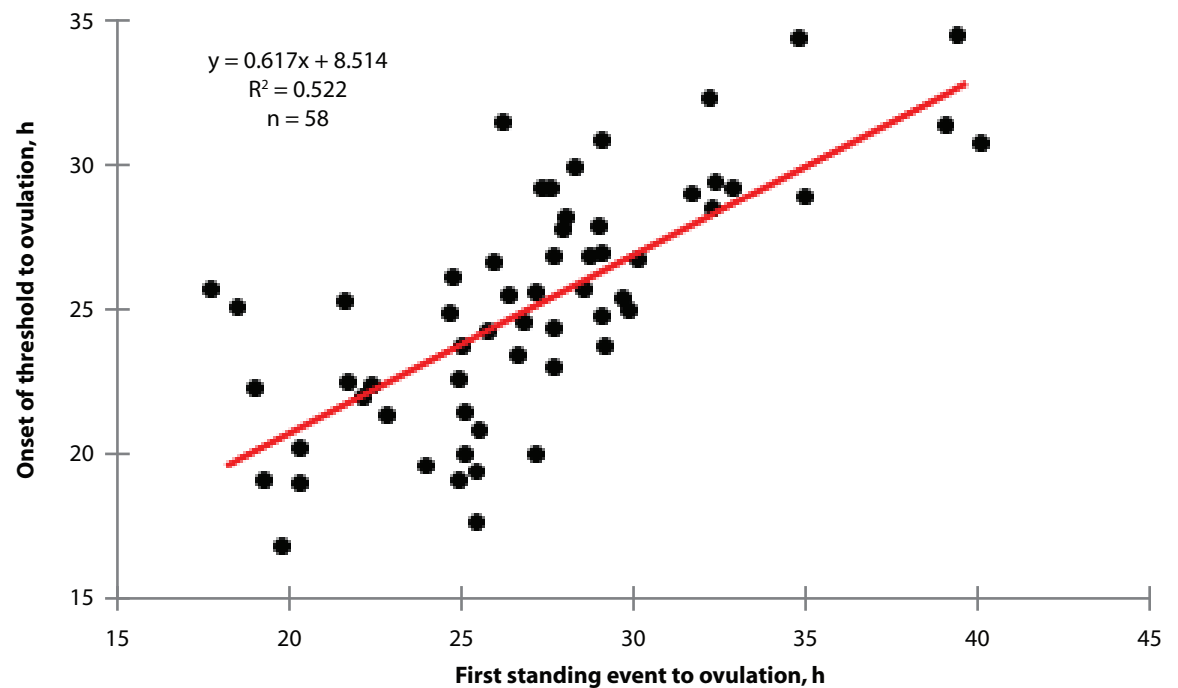


Figure 2. Linear relationship between time of first standing event and increased activity relative to time of ovulation.