Assessment of an Accelerometer System for Detection of Estrus and Timing of Artificial Insemination in Lactating Dairy Cows

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Introduction

Despite the widespread adoption of hormonal synchronization protocols that allow for timed artificial insemination (TAI), detection of behavioral estrus continues to play an important role in the overall reproductive management program on most dairies in the U.S. (Caraviello et al., 2006; Miller et al., 2007). Several challenges for estrus detection on farms include attenuation of the duration of estrous behavior associated with increased milk production near the time of estrus resulting in shorter periods of time in which to visually detect estrous behavior (Lopez et al., 2004), low number of cows expressing standing estrus (Lyimo et al., 2000; Roelofs et al., 2005; Palmer et al., 2010), silent ovulations (Thatcher and Wilcox, 1973; Palmer et al., 2010; Ranasinghe et al., 2010), and reduced expression of estrous behavior due to confinement (Palmer et al., 2010). Whatever the cause, the low efficiency of estrus detection not only increases time from calving to first AI but increases the average interval between AI services (Stevenson and Call, 1983) thereby limiting the rate at which cows become pregnant.

Because of the impact of AI service rate on reproductive performance and the problems associated with visual estrus detection on farms, many technologies have been developed to enhance estrus detection by providing continuous surveillance of behavior including rump-mounted devices and androgenized females (Gwazdauskas et al., 1990), pedometry (Peralta et al., 2005; Roelofs et al., 2005), and radiotelemetry (Walker et al., 1996; Dransfield et al., 1998; Xu et al., 1998). New electronic systems that incorporate accelerometers as a means to associate increased physical activity with estrous behavior in cattle (Holman et al., 2011; Jónsson et al., 2011) have been developed and marketed to the dairy industry. Whereas a large body of literature exists on the accuracy and efficacy of using various technologies to predict ovulation and timing of AI in relation to ovulation in lactating dairy cows, no other studies have investigated accelerometers for such purposes.

Experiment

To assess the use of an accelerometer system for reproductive management, lactating Holstein cows from a commercial dairy farm located in southwestern Wisconsin milking approximately 1,000 cows were used in a field trial, which was performed from August, 2010 to June, 2011. At 14 d after calving, all cows were fitted with an accelerometer (Heatime®, SCR Engineers, Ltd., Netanya, Israel) attached to a neck collar and an electronic identification tag. After each milking, data collected by the accelerometer was read by a transceiver unit placed in an archway at the milking parlor exit and then transferred to the accelerometer herd management software (Data Flow™; Micro Dairy Logic, Amarillo, TX) installed on the on-farm computer. The accelerometer system continuously monitored individual cow activity and recorded average activity for 2 h time periods. The raw activity of individual cows was plotted as a bar graph where each bar represented a 2 h block of time. The onset of activity was defined as the time at which the first bar of raw activity of an estrus event was identified. Duration of activity was defined has the time interval between the beginning and end of activity for an estrus event. Twice daily (a.m. and p.m.), a list of cows determined by the accelerometer system to be eligible for insemination was generated, and cows appearing on the list generated by the accelerometer system were inseminated. Thus, inseminations were conducted twice daily (a.m. and p.m.) by two herd personnel with each cow receiving a single insemination based on activity.

Each week, cohorts of 10 to 15 cows from 46 to 52 DIM were evaluated by transrectal ultrasonography to determine uterine health and record ovarian structures. Cows without signs of uterine disease and at least one follicle ≥ 10 mm in diameter received an i.m. injection of GnRH followed by an i.m. injection of PGF2α 7 d later to synchronize estrus (Figure 1). Transrectal ultrasonography was performed at the time of the PGF2α injection for subsequent determination of ovulatory response to GnRH treatment. A total of 112 cows were enrolled, but only
89 cows that were considered properly synchronized were included in the analyses. Transrectal ultrasonography was performed at the time of the PGF<sub>2α</sub> injection for subsequent determination of ovulatory response to GnRH treatment. Diameter of ovarian structures was estimated and recorded using on-screen background gridlines comprising squares with 10 mm sides in the portable scanner. Ovulation was defined as the presence of a follicle ≥ 10 mm at the initial ultrasound examination at the time of the GnRH injection and the presence of a new corpus luteum in the same location at the subsequent ultrasound examination at the time of the PGF<sub>2α</sub> injection. Thereafter, ovarian ultrasonography was performed 48 h after the PGF<sub>2α</sub> injection and then every 8 h until ovulation occurred or until 96 h, whichever occurred first. Cows failing to ovulate within 96 h of the PGF<sub>2α</sub> injection were re-examined 3 d later (i.e., 7 d after the PGF<sub>2α</sub> injection) to determine whether ovulation had occurred.

Figure 1. Diagram of experimental activities. Cows from 46 to 52 d postpartum received a G-P protocol to synchronize estrus using i.m. injections of GnRH (100 µg) and PGF<sub>2α</sub> (25 mg). Transrectal ultrasonography (US) was used to assess ovarian structures during the protocol and time of ovulation after induction of luteolysis, and blood samples (B) were collected to assess serum progesterone.

Results
The percentage of cows with estrus events detected by the accelerometer system and the distribution of cows by occurrence of estrus and ovulation are presented in Table 1. Throughout the study period, 78% of cows ovulated within 7 d after induction of luteolysis. Of the cows that ovulated, 59% ovulated within 96 h, whereas 41% ovulated from 96 to 168 h (4 to 7 d) after induction of luteolysis. Overall, 71% of cows were detected in estrus by the accelerometer system, and 95% of cows showing estrus ovulated whereas 5% did not ovulate within 7 d of induction of luteolysis. Of the cows not detected in estrus by the accelerometer system, 35% ovulated whereas 65% did not ovulate within 7 d of induction of luteolysis.

Table 1. Percentage of cows determined to be in estrus, and distribution of cows by estrous activity and ovulation after induction of luteolysis based on use of an accelerometer system<sup>1</sup>.

<table>
<thead>
<tr>
<th>Activity and ovulation responses of cows after induction of luteolysis</th>
<th>% (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cows with estrous activity</td>
<td>71 (89)</td>
</tr>
<tr>
<td>Cows with ovulation</td>
<td>95 (63)</td>
</tr>
<tr>
<td>Cows with no ovulation</td>
<td>5 (63)</td>
</tr>
<tr>
<td>Cows with no estrous activity</td>
<td>29 (89)</td>
</tr>
<tr>
<td>Cows with ovulation</td>
<td>35 (26)</td>
</tr>
<tr>
<td>Cows with no ovulation</td>
<td>65</td>
</tr>
</tbody>
</table>

<sup>1</sup>Heatime<sup>®</sup>, SCR Engineers, Ltd., Netanya, Israel.

The duration of estrus activity for cows detected in estrus by the accelerometer system (16.1 ± 4.7 h, range = 4.0 to 28.0; Figure 2) was not affected (<i>P</i> = 0.74) by parity (16.4 vs. 17.2 h for primiparous and multiparous, respectively) or milk production near the time of estrus (<i>P</i> = 0.51). The duration of estrus observed in this experiment is comparable to the mean duration (13.4 h) reported for cows monitored for estrus by visual observation of both primary (standing to be mounted) and multiple secondary signs of estrous behavior (Roelofs et al., 2004). Conversely, duration of estrus activity observed in the present experiment is considerably longer than the mean duration of estrus based on the interval between the first and last standing event of estrus detected using an electronic pressure-sensing system (Dransfield et al., 1998; Xu et al., 1998). Discrepancies between the duration of estrus based on activity or visual observation with that recorded based on standing events are possibly due to the uncoupling of expression of secondary signs of estrus behavior and standing estrus. Indeed, Sveberg et al., (2011) reported that secondary signs of estrous behavior, which can certainly be detected by visual observation or increased activity, increased significantly within 1 to 3 h before the initiation of standing estrus in lactating dairy cows.
We did not expect that ~30% of cows would fail to show estrus within 7 d after the PGF$_{2a}$ injection because a follicle >10 mm was present in all cows at the time of the PGF$_{2a}$ injection, and all cows included in the analysis underwent luteal regression within 48 h after PGF$_{2a}$ treatment. In another study in which cows received two sequential PGF$_{2a}$ injections at 35 and 49 DIM, only 67.9% of cows determined to be cycling by 49 DIM were detected in estrus and inseminated after the second PGF$_{2a}$ injection leading the authors to conclude that issues other than cyclicity status affected efficiency and accuracy of estrus detection (Chebel and Santos, 2010). The percentage of cows that failed to ovulate within the group of cows not detected in estrus was 65% for the accelerometer system suggesting that estrus did not occur in these cows. The remaining 35% of ovulations in cows not detected in estrus may have been silent ovulations (ovulation without estrus), a phenomena described in lactating dairy cows especially during the early postpartum period (Thatcher and Wilcox, 1973; Palmer et al., 2010; Ranasinghe et al., 2010). In addition, 5% of cows detected in estrus failed to ovulate within 7 d after induction of luteolysis. The overall rate of ovulation failure in lactating dairy cows that showed estrus behavior was 6.5% and was greater during the warm than during the cool season (López-Gatius et al., 2005). This rate of ovulation failure represents a small percentage of the population of cows in this experiment and could occur due to failure in the mechanism triggering ovulation (i.e. no LH surge or insufficient LH secretion) or a lack of response by the dominant follicle to the LH surge.
ovulation when detected in estrus using the accelerometer system.

Conclusion
A practical implication of these data is that only two thirds of the cows that were considered properly synchronized would have been inseminated based on the accelerometer system and would go on to ovulate after AI. The remaining cows either would not be inseminated because they were not detected in estrus or would not have a chance to conceive to AI because they would fail to ovulate after estrus. These data underscore the importance of implementing a comprehensive reproductive management program for identification and treatment of cows that would otherwise not be inseminated and to identify those cows failing to ovulate when cycling spontaneously. Based on data from the present experiment using this accelerometer system, the mean time of AI in relation to ovulation was acceptable for most of the cows detected in estrus; however, variability in the duration of estrus and timing of AI in relation to ovulation could lead to poor fertility in some cows.

References


