Comparison of oestrus detection methods in dairy cattle

A. Holman, J. Thompson, J. E. Routly, J. Cameron, D. N. Jones, D. Grove-White, R. F. Smith, H. Dobson

Sixty-seven Holstein-Friesian cows, from 20 days postpartum, were recruited into the study and fitted with both a pedometer (SAE Afikim) and a Heatime neck collar (SCR Engineers) and allocated a heat mount detector (either scratchcard [Dairymac] or KaMaR [KaMaR]) or left with none, relying only on farm staff observation. Common production stressors and other factors were assessed to determine their impact on the ability of each method to accurately detect oestrus and to investigate effects on the frequency of false-positive detections. Only 74 per cent of all potential oestrus periods (episodes of low progesterone) were identified by combining information from all methods. There was no difference between the methods in terms of sensitivity for detecting ‘true oestrus events’ (approximately 60 per cent), with the exception of scratchcards, which were less efficient (36 per cent). Pedometers and KaMaRs had higher numbers of false-positive identifications. No production stressors had any consequence on false-positives. The positive predictive values for neck collars or observation by farm staff were higher than those of other methods, and combining these two methods yielded the best results. Neck collars did not detect any of the nine oestrus events occurring in three cows with a body condition score (BCS) of less than 2, and the efficiency of correctly identifying oestrus was also reduced by high milk yield (odds ratio [OR]=0.34). Pedometer efficiency was reduced by lameness, low BCS or high milk yield (OR=0.42, 0.15 or 0.30, respectively).

DETECTION of oestrus is increasingly being recognised as a major problem in UK dairy herds. Cows are showing fewer behavioural signs of oestrus and for a shorter duration of time, making identification of oestrus more difficult for farmers (Dobson and others 2007). Oestrus has been stated to traditionally last for 10 to 18 hours (Esslemont and Bryant 1976), although some cattle show signs for as short a period as three hours (Hall and others 1989, Roelofs and others 2005). With decreasing submission rates for insemination, getting cows pregnant is becoming more of a challenge, and extended calving intervals are a financial burden (Esslemont and Peeler 1993). Numerous oestrus detection aids are being used in an attempt to improve submission rates, ranging from simple systems such as three-week calendars, Bray charts or heat mount detectors, to ‘high-tech’ automated activity monitors.

The most important factor affecting the efficiency of oestrus detection is that farm staff responsible for checking for oestrus should fully understand the signs and be committed to oestrus detection (Diskin and Sreenan 2000). Continual monitoring is not usually an option on farms, but five 30-minute observation periods throughout the day at times when animals are not subject to management procedures such as feeding or milking, starting early in the morning, identifies 86 per cent of those seen to show oestrus when continually monitored. However, two 30-minute observation periods recognised only 63 per cent of cows in oestrus that were seen when monitored constantly (van Vliet and others 1996).

Cheaper, non-technical options such as pressure-sensitive heat mount detectors can be useful tools for aiding the detection of oestrus when used correctly (Foote 1975), although they are not a substitute for observation as they need regular checking and are more efficient if combined with observations by farm staff. Previous studies have shown heat mount detectors of various varieties, including tail paint, scratchcards and KaMaRs (KaMaR), to provide a high sensitivity (>80 per cent) and positive predictive value (PPV) (>85 per cent) for detecting oestrus in dairy cows (Cavalieri and others 2003). HeatWatch (CowChips), a more expensive product available only in the USA, detects mounts through a pressure-sensitive pad placed on the tailhead of the cow that radiotransmits information. This has proved beneficial, although again more successful when used in combination with visual observation (Peralta and others 2005).

Activity monitors have become widely available in the UK, but require substantial initial financial investment. Work published to date indicates a similar performance of electronic equipment when compared with either the use of heat mount detectors or visual observation by the farmer (Xu and others 1998). Pedometers detect oestrus effectively and appear to be a promising tool for the prediction of ovaulation, and hence their use could improve fertility (Roelofs and others 2005).
2005). It has been suggested that a leg-mounted activity detector (pedometer) can reliably detect oestrus better than the same detector mounted on a neck collar. The collar-mounted activity detector was capable of detecting oestrus reliably only under paddock conditions (Sakaguchi and others 2007).

Various products termed ‘stressors’ have an adverse effect on dairy cow fertility, with lameness, low body condition score (BCS), high somatic cell count (SCC) and high daily milk yield being especially deleterious (Dobson and others 2007, Morris and others 2009). These stressors disrupt the gonadotrophin support required for appropriate follicular growth and ovulation, with consequent effects on fertility and oestrous behaviour (Dobson and Smith 2000, Walker and others 2008). However, it is not clear whether these production stressors would affect the efficiency of heat mount detectors and activity monitors.

The present field trial aimed to compare the accuracy of oestrus detection between farmer observation, heat mount detectors (scratch-cards [Dairymac] or KaMaRs [KaMaR]) and cow activity monitors (neck collars [SCR Engineers] or pedometers [SAE Afikim]) to evaluate their benefit on a UK commercial dairy farm. In addition, the influence of common stressors (lameness, BCS, SCC or milk yield) and other potential risk factors (parity, time postpartum, season, synchronisation, manipulation of the oestrous cycle) was assessed.

Materials and methods
Sixty-seven Holstein-Friesian cows housed on one commercial UK dairy farm were used in the study. The herd comprised a total of 170 cows, which calved throughout the year. Mean annual milk sales per cow were 11,000 litres, with average peak yields of 54 litres per day. At any one time, a group of approximately 80 cows up to four months after calving were housed in a cubicle shed with concrete flooring. Milking of all cows took place three times a day, starting at 05.30, 14.00 and 20.30. Throughout the study, cows had access to a total mixed ration at a feed-fence along a central passage. Feed was pushed up five times a day.

Cows were recruited to the study in batches starting 20 to 40 days postpartum. The cows ranged from being in the first to 11th lactation. All fertility examinations and treatments required during the study were documented as part of normal record-keeping on the farm. Heatime activity collars (SCR Engineers; distributed in the UK by FabDec) had been installed four months previously, and farm staff also monitored the cows by visual observation. Two members of the farm staff were principally responsible for oestrus detection, assisted by three other part-time milking staff. Cows were watched for 10 minutes at 05.20, 10.00, 13.30, 17.00, 20.00 and 23.00 (before and after milkings) and 01.00 (in the morning). Observation was conducted by walking among the cattle while looking for behavioural signs of oestrus such as vulva sniffing/being sniffed, chin-resting/bein chin- rests on, mounting other cows and standing to be mounted, as well as mucoid or bloody vaginal discharge. The layout and lighting (200 lux for 18 hours per day with a six-hour period of 20 lux) permitted easy observation, with an outdoor loafing area being the main congregating place for cows in oestrus. The farm staff continued with the usual routine for visual oestrus detection and recording throughout the trial. Day-book records were reviewed to identify cows deemed to have been demonstrating specific signs of oestrus by the farm staff, and the time when this occurred.

Cattle were recruited to the study in batches every three weeks, and initially the first oestrus was synchronised using a modified Ovsynch protocol (Pursley and others 1995). Twenty-nine cattle were given intra-muscular injections of 5 ml prostaglandin (Lutalyse; Pfizer) and 2.5 ml of a gonadotrophin-releasing hormone analogue (Receptal, Intervet/Schering-Plough Animal Health) on day 0, followed by another injection of 5 ml prostaglandin 10 days later. This was to facilitate another oestrus event to be identified by the heat mount detectors, and the time when this occurred.

A distinction was made later during statistical analysis between this synchronisation treatment and subsequent administration of clinical treatments to manipulate the oestrous cycle.

At recruitment, leg pedometers (Aftag; SÆ Afikim) were placed on all the cows, and heat mount detectors were applied on the scapula following the manufacturer’s instructions. One-third of the cows were fitted with scratchcards (Estrus Alert; Dairymac); rubbing the scratch-card during mounting removes a thin film to expose a brightly coloured layer underneath. One-third had KaMaRs; with these, pressure during mounting ruptures a capsule containing red ink. The remaining one-third of the cows were not given a heat mount detector. Before the study, a list of the cows in the order of their predicted calving dates were compiled. The cows were then allocated to one of the three groups from this list: the first cow was allocated a scratch-card, the second a KaMaR and the third given no mount detector, to assess the observations made by the farm staff. The cows were not seen before being assigned to a group and once allocation was made no changes occurred.

The heat mount detectors were examined daily for a colour change. Detectors were scored on a simple numerical system: 0 No change (not activated), 1 Some colour change (inconclusive), 2 Full colour change (activated). The detectors were replaced after activation to identify any subsequent oestrus.

At the time of entry to the study, all the cows were fitted with neck collars, but access to the neck collar computer output by the farm staff was restricted to half of the herd (cows with odd-numbered identification numbers). This was to ensure that there was a group in which only visual observation was used to identify cows in oestrus (thus, for one-sixth of the cows in the study, the farm staff could not see neck collar data and the cows did not have a heat mount detector). Neck collar data were downloaded in two-hour blocks at the milking parlour exit into a dedicated computer program (Dataflow; SCR Engineers), and a value of greater than 4.7 sd above the mean of the previous eight two-hourly blocks was used to identify oestrus.

Foot-trimming and antibiotic treatment for udder infections. These actions were recorded in the farm day-book, and all reproductive
examinations and treatments were recorded both in the day-book and
directly into the Interherd computer program (PAN Livestock).

The season of each identified oestrus event was recorded, with a
distinction being made for statistical analysis between summer (April
To September) and winter (October to March). The parity of each ani-
mal was noted and subsequently categorised into four groups (parity
1, parity 2, parity 3, and parity 4 and above) for statistical analysis.

The PPVs generated for combinations of the various 'low-tech'
methods with 'high-tech' methods indicated that using neck col-
las alongside observation by farm staff yielded the most accurate
level of oestrus detection (PPV 91.7 per cent [95 per cent CI 77.5
and 98.2]) (Table 1). The PPVs for neck collars or observation by farm
staff alone were higher than all other individual methods of detection
(P<0.003) (Table 1).

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and 98.2]) (Table 1). The sensitivity of this combination was greater
than 98 per cent (95 per cent CI 96.7 to 99.8) (P<0.003) (Table 1).

The results are presented as three groups: cows without a heat mount
detector when neck collar information was not accessible
to the farm staff, cows without a heat mount detector when
neck collar information was accessible to the farm staff,
and cows with a heat mount detector. The data relating to observations by farm staff are
presented as three groups: cows without a heat mount detector when
neck collar information was not accessible to the farm staff, cows without
a heat mount detector when neck collar information was accessible to the farm staff,
and cows with a heat mount detector.

All individual detection methods demonstrated equivalent sensi-
tivity except for scratchcards, which were less efficient (P<0.003
(Table 1). The PPVs for neck collars or observation by farm staff
alone were higher than all other individual methods of detection
(P<0.003) (Table 1).

This process was continued until no further variables could be added to
produce the final model. Interactions between variables in the final
model were considered for inclusion and retained if they improved
model fit as judged by the likelihood ratio test. No significant inter-
actions were identified.

Results

A total of 266 oestrus events were recorded from June 1 to December
18, 2009, of which 189 coincided with periods of low milk progester-
one concentrations (possible oestrus events). Only 74 per cent of the
possible oestrus events were identified by one or more of the methods
evaluated; 26 per cent of periods of low progesterone remained unde-
tected by any method (only 6 per cent of true oestrus events were
before the first luteal phase postpartum).

On several separate occasions, the neck collars or pedometer sys-
tems were not operational (but never simultaneously). This was due
to mixtures of technical or human errors, for example, power outage
and equipment not automatically resetting, malfunction of the equip-
ment, inappropriate computer updating or analysis, or failure to enter
information on to the computers correctly. Hence, neck collar data
were unavailable for 43 of 189 (22.7 per cent) oestrus events, and ped-
ometer data were unavailable for 31 of 189 (16.4 per cent) oestrus
events. The following data have not been amended for these failures as
they would influence immediate insemination decisions on-farm.

Table 1 outlines the performance of each individual oestrus detec-
tion method as well as combinations of technological and simpler
methods: scratchcards, KaMaRs, neck collars, pedometers and obser-
ation by farm staff. The data relating to observations by farm staff are
presented as three groups: cows without a heat mount detector when
neck collar information was not accessible to the farm staff, cows without
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level of oestrus detection (PPV 91.7 per cent [95 per cent CI 77.5
and 98.2]) (Table 1). The sensitivity of this combination was greater
than that of neck collars alone (75 per cent [95 per cent CI 59.7 to
86.8]) v 38.9 per cent [95 per cent CI 50.5 to 67.0], P=0.05; mean
difference of 16.1 per cent) (Table 1), but their PPVs were not dif-
ferent (P=0.49) (Table 1). There was no difference in sensitivity
between observation by farm staff alone or farm staff combined with

### Table 1: Sensitivity and positive predictive values for different oestrus detection methods used (individually or in combination) in dairy cows, with 95 per cent confidence intervals

<table>
<thead>
<tr>
<th>Detection method</th>
<th>Number of periods of low progesterone</th>
<th>Number of true-positive activations</th>
<th>Sensitivity (%) (95% CI)</th>
<th>Positive predictive value (%) (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual methods</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scratchcard</td>
<td>46</td>
<td>23</td>
<td>35.9 (24.3-48.9)</td>
<td>63.9 (46.2-79.2)</td>
</tr>
<tr>
<td>KaMar</td>
<td>67</td>
<td>38</td>
<td>56.7 (44.0-68.8)</td>
<td>61.3 (48.1-73.4)</td>
</tr>
<tr>
<td>Farm staff (alone)</td>
<td>23</td>
<td>13</td>
<td>56.5 (34.5-76.8)</td>
<td>92.9 (66.1-99.9)</td>
</tr>
<tr>
<td>Farm staff (when neck collar data were visible)</td>
<td>35</td>
<td>24</td>
<td>68.6 (50.7-83.1)</td>
<td>82.8 (64.2-94.2)</td>
</tr>
<tr>
<td>Farm staff</td>
<td>58</td>
<td>37</td>
<td>63.8 (50.1-76.0)</td>
<td>86.9 (72.1-94.7)</td>
</tr>
<tr>
<td>Neck collar</td>
<td>146</td>
<td>86</td>
<td>58.9 (50.5-67.0)</td>
<td>93.5 (86.3-97.6)</td>
</tr>
<tr>
<td>Pedometer</td>
<td>158</td>
<td>100</td>
<td>63.3 (53.3-70.8)</td>
<td>73.5 (46.2-79.2)</td>
</tr>
<tr>
<td>Combinations of methods</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck collar + scratchcard</td>
<td>57</td>
<td>39</td>
<td>68.4 (54.8-80.1)</td>
<td>72.2 (58.4-83.5)</td>
</tr>
<tr>
<td>Neck collar + KaMar</td>
<td>45</td>
<td>34</td>
<td>75.6 (60.5-87.1)</td>
<td>63.0 (48.7-75.7)</td>
</tr>
<tr>
<td>Neck collar + farm staff</td>
<td>44</td>
<td>33</td>
<td>75.0 (59.7-86.8)</td>
<td>91.7 (77.5-98.2)</td>
</tr>
<tr>
<td>Pedometer + scratchcard</td>
<td>57</td>
<td>38</td>
<td>66.7 (52.9-78.6)</td>
<td>59.4 (46.4-71.5)</td>
</tr>
<tr>
<td>Pedometer + KaMar</td>
<td>58</td>
<td>44</td>
<td>75.9 (62.8-86.1)</td>
<td>66.3 (48.1-71.5)</td>
</tr>
<tr>
<td>Pedometer + farm staff</td>
<td>43</td>
<td>32</td>
<td>74.4 (58.8-86.5)</td>
<td>68.1 (52.9-80.9)</td>
</tr>
</tbody>
</table>

Statistical comparisons were made using data from farm staff (alone), and not from farm staff (when neck collar data were visible) or farm staff (all)
1 Within a column for individual methods, different from other values, P<0.003
2 Within a column for combination of methods, different from other values, P=0.003

G Confidence interval

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neck collars (75 per cent [95 per cent CI 59.7 to 86.8] v 56.5 per cent [95 per cent CI 34.5 to 76.6]; P=0.14), nor any difference in PPV (P=0.96) (Table 1).

Consecutive activations (score 1) were seen on 34 occasions for scratchcards and 22 occasions for KaMaRs. While a partial colour change (score 1) occurred with both types of heat mount detector, they were easy to differentiate from full activation. The cow brushes in the loaming area may have presented a problem by marking the scratchcards, but left obvious brush strokes and therefore did not cause any confusion. On a number of occasions, KaMaRs were observed being falsely activated by a knock in the cubicles, usually from a cow in an adjacent cubicle kicking the KaMaR while manoeuvring to re-position. These incidents caused full activation, and thus led to false-positives being recorded. No analysis was performed on consecutive activations of the heat mount detectors.

**False-positives**

False oestrus occurred on 77 occasions, with eight of these events being detected by two oestrus detection methods. In total, false oestrus was exhibited by 38 cows (58 per cent) on at least one occasion, but 18 cows had only one false-positive event. Pedometers and KaMaRs were over-represented in the numbers of false-positives, with 36 and 24 events, respectively (42 and 28 per cent of all the false-positives), as revealed by their low PPVs.

Of the 26 events falsely identified by pedometers, 16 occurred in seven animals (one cow with four events, one cow with three events, and four with two). Of the total 26 events, 16 occurred in non-pregnant cows and 10 occurred during pregnancy, and all occurred when there were one to six other cows also in oestrus on the same day. Of the events during pregnancy, two were between 10 and 12 days after insemination, six were between 18 and 24 days and two were between 32 and 34 days. For four of the events falsely identified by pedometers, very detailed behaviour data were available from a concurrent study. While many of the behaviours could have been displayed in the general melee of a bulling group (licking and chin-resting), there was evidence of increased mucus production by each animal. Regrettably, the neck collar system was broken for these animals at this time. Such detailed behaviour data were not available for the remaining 22 pedometer false-positive events.

Lameness score, BCS, SCC, milk yield, parity and season had no influence on the incidence of false-positive oestrus events (data not shown). Increasing time postpartum led to an increased chance of the cow demonstrating a false-positive (OR=1.69 [95 per cent CI 1.26 to 2.27]; P<0.01, for every 50-day increase in time postpartum). The odds of a false oestrus event occurring was more likely in cows with oestrus synchronised on entry to the study (OR=2.09 [95 per cent CI 1.16 to 3.76]; P=0.01). Administration of a clinical treatment to manipulate the oestrous cycle significantly decreased the likelihood of a false-positive oestrus event occurring at the immediate post-treatment oestrus (OR=0.14 [95 per cent CI 0.05 to 0.40]; P<0.01).

**Factors affecting the efficiency of oestrus detection examined by logistic regression modelling**

Since oestrus events were clustered within cows, that is, some cows had more than one oestrus event during the study period, multilevel modelling was used with cow identity as a random effect. Table 2 outlines the number of correctly identified periods of low progesterone associated with each investigated confounding factor for each oestrus detection method.

None of the recorded confounders had a significant impact on the performance of scratchcards or KaMaRs. Since only 15 of 23 true oestrus events were detected by the farm staff alone, multivariable regression was not attempted (the sample size was too small). Furthermore, none of the nine oestrus events in cows with a BCS of less than 2 were detected by neck collars, so BCS could not be included in the modelling exercise.

The odds of a true oestrus being detected by neck collars was significantly reduced by high milk yield compared with low yield (OR=0.34 [95 per cent CI 0.15 to 0.79]; P=0.04) (Table 2). The odds of detecting a true oestrus by pedometer were significantly reduced in lame compared with non-lame cows (OR=0.42 [95 per cent CI 0.17 to 1.02]; P=0.05), in cows with low versus acceptable BCS (OR=0.15 [95 per cent CI 0.02 to 1.26]; P=0.08) and in cows with high versus low milk yields (OR=0.5 [95 per cent CI 0.09 to 0.98]; P=0.04).

**Discussion**

The present study found comparable sensitivities for each of the methods tested, with the exception of scratchcards, which had poor...
sensitivity. Considering both sensitivity and PPVs, the most useful results for use on-farm were obtained when combining observation by farm staff with neck collars, although the sensitivity was not significantly greater than that of farm staff observation alone. This is surprising, as it might have been assumed that most farmers would interact with the output from computer-assisted systems, either by seeing the output and going to check on a cow in oestrus, or wondering whether a cow was in oestrus and checking on the computer output. However, this study was specifically designed to compare each system independently, and then look at possible additive effects. There were no additive effects. However, when looking retrospectively at combinations of methods, relying on neck collars alone resulted in 16 per cent fewer events being detected than if additional farm staff observations were made. Any comparisons between farm staff observation alone and the combination of farm staff and neck collars must be considered conservatively due to the low numbers of oestrus events in the ‘farm staff alone’ group. Both neck collars and pedometers are tools with which farm staff can interact, adjust and interpret. Settings can be adjusted to suit each farm, and past activities can be reviewed to maximise decisions, for example, in relation to previous oestrus events or other farm procedures (for example, moving cows from place to place).

While six periods of visual observation by farm staff were used on this farm, at least four were around milking times, which is known not to be ideal (Pennington and others 1986). Two-hour-half observation periods using a scoring scheme incorporating subtle signs of oestrus recognised 74 per cent of oestrus events with no false identifications (van Eerdenburg and others 1996). Utilising that scoring method during dedicated observation periods may prove cost-effective and add to the accuracy of oestrus identification by farm staff alone. The high rate of false-positives from pedometers in the present study concurs with that reported by Lehrer and others (1992). A potential explanation in the present study is that the pedometers collected data in approximately eight-hour blocks. The number of false-positives may be reduced if this was changed to more frequent blocks per day, as incorporated in a new modified pedometer that still requires independent validation (Pedometer Plus; SAE AfiKim). In the present study, seven cows accounted for 16 false-positives, indicating an individual cow disposition that lead to false oestrus detections by pedometers. Furthermore, there was additional physiological evidence (from another concurrent study) of increased mucus during four periods of increased follicular growth. This is supported by the timing on days 10 to 12 and 18 to 24 relative to earlier positively identified events. Within each farm for each technological method, it is possible to raise the threshold value indicating increased activity to be mounted, as well as spending less time on their feet (Dobson and others 2007). The heat mount detectors require the cow to stand to be mounted only once to be activated, and the farmer needs to observe just one episode of standing to identify the animal as being in oestrus. The activity monitors, however, rely on increased activity over a reasonably sustained period of time before the cow is identified, thus, the effects of higher milk yield may not be easily identified by activity monitoring methods. High-yielding animals may also spend more time standing still while feeding, due to their increased nutritional requirements compared with lower-yielding cattle, or lie for longer while ruminating, having less ‘spare time’. The present data from oestrous cows indicate that the sensitivity of neck collars (with multidirectional sensors able to detect more agitated general behaviour) was not different from the sensitivity of pedometers (measuring the number of steps per day).

A total of 26 per cent of potential oestrus periods (low progesterone) were not detected by any method. This is an area of particular concern for both farmers and veterinarians. No oestrus detection system is flawless, and further testing of all the methods on a variety of farms will allow more robust comparisons to be made, and conclusions to be drawn on the efficiency and accuracy of the methods over a wide range of farms and management systems.

Acknowledgements

This study was carried out by AH in partial fulfilment of the requirements for the Diploma in Bovine Reproduction, University of Liverpool. The authors thank the farm staff for their assistance and support with the project. The neck collars were donated by Tesco in support of the Tesco Dairy Centre of Excellence, University of Liverpool. Pedometers were loaned by Fullwood.

References


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Veterinary Record 2011 169: 47 originally published online July 5, 2011
doi: 10.1136/vr.d2344

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