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The effect of housing condition on the performance of two types of activity meters to detect estrus in dairy cows

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ABSTRACT

When the daily routine of a cow is disturbed, it may have a detrimental effect on the performance of activity meters to detect estrus. It is possible that during the pasture period, the daily routine of cows is disturbed, adversely affecting the performance of activity meters to detect estrus which does not happen when the cows are housed indoors. The objective of this study was to investigate whether housing conditions (pasture or indoor) affected the performance of activity meters to detect estrus in dairy cows. In this research, two types of activity meters were used, an activity meter attached to the leg and one mounted on the neck. Cows of two different herds were equipped with the Smarttag Leg and the Smarttag Neck (Nedap livestock management, Groenlo, the Netherlands). The study began during the pasture period (September) and ended during the indoor period (January). The pasture period ended at the beginning of November. So, about two months of pasture period and two months of indoor period were studied. Milk samples were collected twice a week during the morning milking and true estrus was determined by milk progesterone concentrations. In total, the dataset consisted of 95 true estrous periods and 1992 true non-estrous days of 56 cows for the pasture period and 138 true estrous periods and 3164 true non-estrous days of 65 cows for the indoor period. Overall, no differences in sensitivity, positive predictive value (PPV) and specificity were found between the pasture and indoor period for both types of sensors. There was also no difference in the performance between leg and neck activity meters. Sensitivity was between 76 and 82%, PPV was between 87 and 92% and specificity was between 99 and 100%. In conclusion, the sensitivity, PPV and specificity did not differ between the pasture and indoor period. This means that, in our study, the performance of both types of activity meters to detect estrus is not affected by housing conditions.

1. Introduction

Good and accurate detection of estrus is important but challenging for a dairy farmer. Many estrous detection tools are available for the farmer [1]. Pedometers to measure the number of steps and neck-mounted activity meters are commonly used. These activity meters register the activity of individual cows during a certain time period and compare that activity with the expected activity of that specific cow. When the activity exceeds a certain threshold an estrous alert is generated [2]. The performance of these activity meters can be assessed by various parameters such as sensitivity, positive predictive value (PPV) and specificity [3]. Sensitivity and PPV show great variation between studies. For pedometers, sensitivity of 63%–89% and PPV of 71%–84% were found. For neck mounted activity meters, sensitivity of 36%–90% and PPV of 67%–94% were found (reviewed by Ref. [4]). When sensitivity is low, many estrous periods are not detected, and when PPV is low, many estrous alerts are false. Estrous alerts are generated based on the average activity of the individual cow. When the routine of a cow is disturbed, it may have a detrimental effect on the performance of activity meters to detect estrus. In the Netherlands cows are being pastured for part of the year when weather and soil conditions allow pasturing. In many cases the distance to the pasture changes frequently. Because of irregularity in the activity pattern of cows during the pasturing period, performance of activity meters to detect estrus could be adversely affected. In a study in which standing heat was detected by radio telemetry it was found that the sensitivity of estrous detection for cows kept on

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pasture was greater than for cows housed indoors [5]. In studies that use pedometers or neck-mounted activity collars to detect estrus, housing conditions usually stay the same during the study period: cows are either kept on pasture [6–8] or indoors [9,10]. So, the effect of housing conditions on activity meters has not been studied yet. The objective of this study was to assess whether the performance of pedometers (Smarttag Leg) or neck-mounted activity meters (Smarttag Neck) was affected by housing conditions, i.e.cows kept partially on pasture or cows kept indoors.

2. Materials and methods

2.1. Animals and housing

This study was conducted between September 2014 and January 2015 on two commercial dairy herds in the Netherlands. Herd 1 consisted of 116 Holstein-Friesian dairy cows with a mean annual milk production of 8744 kg per cow. Herd 2 consisted of 134 mainly Red Holstein-Friesian dairy cows with a mean annual milk production of 8408 kg per cow. Cows were milked twice a day. The study began during the pasture period, September, and ended halfway the indoor period in January. The pasture period ended at the beginning of November. So, about two months of pasture period and two months of indoor period were studied. During the pasture period, herd 1 was managed under a continuous grazing system in which the cows were pastured during the day, when the weather conditions were appropriate, i.e. not too wet. Herd 2 was kept under rotational grazing during the pasture period, changing pasture every three to four days depending on grass availability and weather conditions. Cows were housed indoors in free stalls with cubicles and slatted floors in both herds.

2.2. Activity meters

Detection of estrus was performed using activity meters. All cows were equipped with the Smarttag Leg and the Smarttag Neck (Nedap livestock management, Groenlo, the Netherlands). The Smarttag Leg records the number of steps and compares every 2-hourly time period with the same 2-hourly time period of the preceding ten days for the same cow. When the number of steps exceeds a certain threshold for at least 2 consecutive periods, an estrous alert is generated. This alert is corrected for the herd-activity level. The Smarttag Neck operates the same way but instead of number of steps it records neck movements.

2.3. Milk sampling and progesterone assay

Milk samples were collected twice a week during the morning milking, starting from 20 days after calving until a cow was diagnosed pregnant. At the beginning of the experiment, 56% and 58% of the cows were diagnosed pregnant in herd 1 and 2, respectively. At the beginning of the indoor period, 59% and 61% of the cows were diagnosed pregnant in herd 1 and 2, respectively. For herd 1, milk samples per cow were collected from the mixing glass in the milking parlor. For herd 2, the milk was collected after the first milk let down directly from one quarter of the udder in the milking parlor. The milk samples were immediately stored at -18° Celsius until assayed.

Progesterone concentration in milk was measured using a commercial ELISA kit (Ridgeway Science, Gloucester, UK). For milk with progesterone concentrations between 2 and 20 ng/ml, the intra-assay and inter-assay coefficients of variation were 5.8% and 13.4%, respectively.

2.4. Interpretation of estrous alerts and performance of activity meters

Alerts generated by the activity meters were compared with true estrous periods. A true estrous period was defined as 1) a marked decrease of progesterone concentration in consecutive samples (at least under 5 ng/ml) followed by an increase in at least two consecutive samples or 2) when progesterone concentrations were low in at least the first four samples at the start of sampling, true estrus was defined when a marked increase (at least over 10 ng/ml) in concentration occurred based on progesterone profiles of individual cows. When an estrous alert coincided with a true estrous period, the alert was defined as true positive (TP). When an estrous alert did not coincide with a true estrous period, the alert was defined as false positive (FP). When no estrous alert was generated during a true estrous period, it was defined as false negative (FN). All days except for the days of the true estrous period were considered as true non-estrous days. When during these days no estrous alert was generated such a day was defined as true negative (TN).

The performance of the activity meters was based on the sensitivity, PPV and specificity. Sensitivity was calculate as TP/(TP + FN)*100%. PPV was calculated as TP/(TP + FP)*100% and specificity was calculated as TN/(TN + FP)*100% [3].

2.5. Data analysis

All cows that had had at least one true estrous period during the pasture period or the indoor period were included in the dataset. All analyses were performed using SPSS statistic 21. The data was checked for differences in sensitivity, PPV and specificity between activity meter (neck or leg) and between periods (pasture or indoor) using Pearson Chi-square tests. Type of activity meter was analyzed within a period and period was analyzed for each type of activity meter. To check for herd differences, the sensitivity, PPV and specificity between herds for each period and type of activity meter was analyzed using a Pearson Chi-square test. The number of days after calving on the day of true estrus was not normally distributed which was checked with the Shapiro-Wilk test of normality. Difference in number of days after calving between periods was analyzed using a Mann-Whitney *U* test. P-values <0.05 were defined as a significant difference.

3. Results

Nineteen cows had at least one true estrus during the pasture period and 38 cows during the indoor period. Another 37 cows had at least one true estrus during both periods. In total, the dataset consisted of 95 true estrous periods and 1992 true non-estrous days of 56 cows for the pasture period and 138 true estrous periods and 3164 true non-estrous days of 65 cows for the indoor period.

During the pasture period, 23 out of the 95 estrous periods were not detected by the leg activity meter and 17 were not detected by the neck activity meter. False estrous alerts were given by the leg activity meter six times and 11 times by the neck activity meter. During the indoor period, 29 out of the 138 estrous periods were not detected by the leg activity meter and 30 were not detected by the neck activity meter. False estrous alerts were given by the leg activity meter 11 times and 16 times by the neck activity meter. No difference in days after calving between pasture (73 ± 34 days) and indoor period (83 ± 47 days) was found.

Overall, no differences in sensitivity, PPV and specificity were found between the pasture and indoor period for both types of sensors (Fig. 1), nor was any difference found in the performance between leg and neck activity meters. Sensitivity was between 76

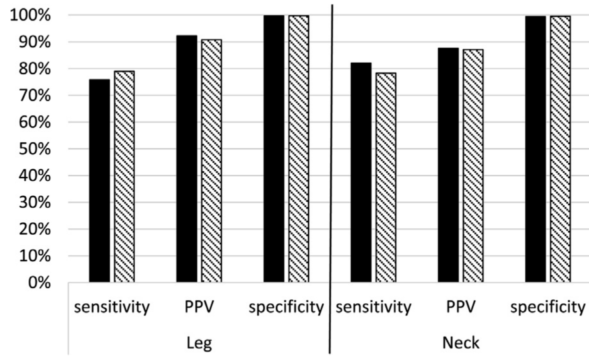

Fig. 1. Overall percentages of sensitivity, positive predictive value (PPV) and specificity during pasture (black bars) and indoor periods (striped bars) for activity meters attached to the leg and neck.

Table 1
Percentages of sensitivity, positive predictive value (PPV) and specificity during pasture and indoor period for activity meters attached to the leg and neck per herd.

Sensor type		Pasture		Indoor	
		Herd 1	Herd 2	Herd 1	Herd 2
Leg	sensitivity	70.6	78.7	79.3	78.8
	PPV	88.9	94.1	93.9	88.7
	specificity	99.6	99.8	99.8	99.6
Neck	sensitivity	85.3	80.3	75.9	80.0
	PPV	100[a]	81.7[b]	91.7	84.2
	specificity	100[a]	99.2[b]	99.7	99.4

[a, b] Different superscripts indicate significant difference ($P < 0.05$) between herds within each period.

and 82%, PPV was between 87 and 92% and specificity was between 99 and 100%.

Herd 1 had a greater PPV and specificity with the neck activity meter during the pasture period compared to herd 2 (Table 1). No other differences were found in performance of the activity meters between herds were found.

4. Discussion

In the Netherlands the pasture period begins approximately at the beginning of May and ends approximately at the beginning of October. The hours spent on pasture depend on weather and grassland conditions and can vary during the pasture period. The method of pasturing can influence daily cow activity levels, with rotational grazing for example, the distance to the pasture can differ from day to day. The basal activity in the same 2-hourly period could vary more in the pasture period than in the indoor period, leading to an increased standard deviation. As an estrous alert is generated based on the mean activity and the standard deviation of the same 2-hourly period for the 10 preceding days [2], a greater standard deviation could result in more false negative estrous alerts, resulting in a lower sensitivity. On the other hand, false positive estrous alerts could occur more often during the pasture period due to high activity of individual cows. This high activity which is not associated with estrus, could occur especially during the beginning of the pasture period when cows are getting used to being on pasture. Furthermore, varying distances to the pasture could result in more false positive estrous alerts, lowering the PPV, even though the activity is corrected for herd level activity.

The sensitivity, PPV and specificity of the leg and neck activity meter in our study did not differ between the pasture- and indoor periods. The study started half way through the pasture period. It is possible that at the beginning of the pasture period more FP or FN alerts are generated because the cows have to get used to their changed housing conditions. As the activity is compared with the activity from the preceding 10 days, it could be that in the first days of the pasture period the performance of the activity meter to detect estrus is adversely affected, because of a higher standard deviation. This has to be further investigated. To our knowledge no other studies on the performance of activity meters for cows kept on pasture compared with cows kept indoors have been conducted.

In a study in which estrous detection was performed with a device that automatically registered standing heat by a pressure sensing device mounted anterior to the tail head, sensitivity and PPV was greater during the pasture period than during the indoor period [5]. It could be that the pasture is less slippery than the indoor flooring which allows the cows to show standing heat more often. It can be hypothesized that when cows have more grip in the pasture, the activity associated with estrus during the pasture period is also increased compared to the indoor period. This could mean that the sensitivity of estrous detection by activity meters is greater during the pasture period. This was not the case in our study. As already mentioned, it could also be that because cows have a more irregular daily pattern during the pasture period, sensitivity and/or PPV is adversely affected during this period. Perhaps both factors contribute positively and negatively to the performance of activity meters during the pasture period thus counterbalancing the differences.

The sensitivity of the leg activity meter during the indoor period (76%) was comparable with the sensitivity of leg activity meters found in other studies (63–81%) in which cows were kept indoors [9,11,12]. The PPV during the indoor period (92%) was comparable with another study that found a PPV of 93% with the same type of leg activity meter [2] but was greater than other studies that found a PPV of 71% [9] and 74% [11]. In all studies, the specificity is close to 100%, because of the numerous periods of true non estrous periods (TN) compared with the number of true estrous periods (TP) [6,13,14].

In our study, the sensitivity of the neck activity meter during the indoor period (78%) was greater than found in other studies (36–62%) in which cows were kept indoors, whereas the PPV (87%) was about the same compared with those studies (83–94%) [9–11]. In contrast, during the pasture period the sensitivity of the neck activity meter (82%) was comparable with that found in other studies (72–90%) in which cows were kept on pasture, whereas the PPV (88%) was greater compared with those studies (67–78%) [6–8,13]. Several factors, such as the algorithm on which an estrous alert is based, number of animals in estrus at the same time, ovulation number, type of golden standard can also have an effect on the number of FN and FP alerts [4]. As all these factors can differ between studies, it is difficult to explain differences found between studies. In our study, there were no FP alerts in herd 1 during the pasture period using the neck activity meter. It is not clear which factors contributed to this very good performance.

In conclusion, the sensitivity, PPV and specificity did not differ between the pasture and indoor period. This means that, in our study, the performance of both types of activity meters to detect estrus were not affected by housing conditions.

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References

[1] Saint-Dizier M, Chastant-Maillard S. Towards an automated detection of oestrus in dairy cattle. Reprod Domest Anim 2012;47:1056–61.
[2] Roelofs JB, van Eerdenburg FJCM, Soede NM, Kemp B. Pedometer readings for estrous detection and as predictor for time of ovulation in dairy cattle. Theriogenology 2005;64:1690–703.
[3] Roelofs J, López-Gatius F, Hunter RHF, van Eerdenburg FJCM, Hanzen C. When is a cow in estrus? Clinical and practical aspects. Theriogenology 2010;74:327–44.
[4] Roelofs JB, van Erp-van der Kooij E. Estrus detection tools and their applicability in cattle: recent and perspectival situation. Anim Reprod 2015;12:498–504.
[5] Palmer MA, Olmos G, Boyle LA, Mee JF. Estrus detection and estrus characteristics in housed and pastured Holstein-Friesian cows. Theriogenology 2010;74:255–64.
[6] Kamphuis C, DelaRue B, Burke CR, Jago J. Field evaluation of 2 collar-mounted activity meters for detecting cows in estrus on a large pasture-grazed dairy farm. J Dairy Sci 2012;95:3045–56.
[7] Aungier SPM, Roche JF, Sheehy M, Crowe MA. Effects of management and health on the use of activity monitoring for estrus detection in dairy cows. J Dairy Sci 2012;95:2452–66.
[8] Talukder S, Thomson PC, Kerrisk KL, Clark CEF, Celi P. Evaluation of infrared thermography body temperature and collar-mounted accelerometer and acoustic technology for predicting time of ovulation of cows in a pasture-based system. Theriogenology 2015;83:739–48.
[9] Chanvallon A, Coyral-Castel S, Gatien J, Lamy J-M, Ribaud D, Allain C, et al. Comparison of three devices for the automated detection of estrus in dairy cows. Theriogenology 2014;82:734–41.
[10] Michaelis I, Burfeind O, Heuwieser W. Evaluation of oestrous detection in dairy cattle comparing an automated activity monitoring system to visual observation. Reprod Domest Anim 2014;49:621–8.
[11] Holman A, Thompson J, Routly JE, Cameron J, Jones DN, Grove-White D, et al. Comparison of oestrus detection methods in dairy cattle. Vet Rec 2011;169:47–52.
[12] de Mol RM, Kroeze GH, Achten JMFH, Maatje K, Rossing W. Results of a multivariate approach to automated oestrus and mastitis detection. Livest Prod Sci 1997;48:219–27.
[13] Hockey C, Morton J, Norman S, McGowan M. Evaluation of a neck mounted 2-hourly activity meter system for detecting cows about to ovulate in two paddock-based Australian dairy herds. Reprod Domest Anim 2010;45:e107–17.
[14] Jónsson R, Blanke M, Poulsen NK, Caponetti F, Højsgaard S. Oestrus detection in dairy cows from activity and lying data using on-line individual models. Comput Electron Agric 2011;76:6–15.