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Short communication: Early modification of the circadian organization of cow activity in relation to disease or estrus

Isabelle Veissier,*†[1] Marie-Madeleine Mialon,*† and Karen Helle Sloth‡
*INRA, UMR1213 Herbivores, F-63122 Saint-Genès-Champanelle, France
†VetAgro Sup, Clermont Université, UMR1213 Herbivores, BP 10448, F-63000, Clermont-Ferrand, France
‡GEA Farm Technologies GmbH, Nørsskovvej 1B, DK-8660 Skanderborg, Denmark

ABSTRACT

Biological rhythms are an essential regulator of life. There is evidence that circadian rhythm of activity is disrupted under chronic stress in animals and humans, and it may also be less marked during diseases. Here we investigated whether a detectable circadian rhythm of activity exists in dairy cows in commercial settings using a real-time positioning system. We used CowView (GEA Farm Technologies) to regularly record the individual positions of 350 cows in a Danish dairy farm over 5 mo and to infer the cows' activity (resting, feeding, in alley). We ran a factorial correspondence analysis on the cows' activities and used the first component of this analysis to express the variations in activity. On this axis, the activities obtained the following weights: resting = −0.15; in alleys = +0.12; feeding = +0.34. By applying these weights to the proportions of time each cow spent on each of the 3 activities, we were able to chart a circadian rhythm of activity. We found that average level of activity of a cow on a given day and its variations during that day varied with specific states (i.e., estrus, lameness, mastitis). More specifically, circadian variations in activity appeared to be particularly sensitive and to vary 1 to 2 d before the farmer detected a disorder. These findings offer promising avenues for further research to design models to predict physiological or pathological states of cows from real-time positioning data.
Key words: dairy cow, animal health, precision livestock farming, behavioral rhythm

Short Communication

Biological rhythms are an essential regulator of life (Foster and Kreitzman, 2014; Smolensky et al., 2016). Diurnal animals are more active during the day whereas nocturnal ones are more active at night, and this pattern is species-specific. Evidence exists that circadian rhythm of activity is disrupted under chronic stress in animals and humans. For instance, rodents (nocturnal species) show more activity during the daylight period and less during the dark period when they are submitted to repeated stressors or inescapable electrical shocks (Stewart et al., 1990; Solberg et al., 1999). The organization of activity also appears disrupted in calves under stress, which show less activity at night but more at the very beginning or end of the daylight period when submitted to social mixing (Veissier et al., 2001). In cattle, circadian variations of activity were found to be less marked 2 d before the occurrence of symptoms of pneumonia (Veissier et al., 1989). These results were obtained by coincidence during an experiment on the stabilization of activity rhythms after the cattle were turned from pasture to indoor conditions and during which an outbreak of pneumonia occurred. These findings were never subsequently confirmed, due to the heavy observational input required; however, today's precision livestock farming technologies can automatically measure several characteristics, including activity of the animals. Here we used a real-time locating system (**RTLS**) to infer cows' behavior in a commercial dairy herd for several months. First we tested whether we could detect a circadian rhythm of activity of the cows from the RTLS data. Then we investigated whether the average level of activity during the day or its circadian variations were disturbed before the farmer detected signs of disease and mentions it in farm records. If such a relation could be established, then RTLS could be used for an integrated management of animal health, helping to identify diseased animals at an early stage and, thus, make it possible to find an earlier cure (probably using less medicine) and limit the spread of disease in a herd by isolating the diseased animal.

We followed 350 dairy cows from a Danish producer for 5 mo. Measurements, diet manipulations, housing, and handling of the animals or any other environment or management factors were all part of the on-farm

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[1]Corresponding author: isabelle.veissier@clermont.inra.fr

routine; thus, our observations did not require any intervention. The cows were either Danish Holstein (75%) or Red Danish (25%) that produced on average more than 10,000 L of milk/yr. The cows were kept indoors year round in a barn equipped with cubicles and an automatic milking system (**AMS**; with 6 milking robots, acquired in 2009; VMS, Delaval, Kolding, Denmark). The lights were on all day, but were reduced from 2200 to 0600 h. The cows had to go through the AMS to move from the resting area (with cubicles) to the feeding area. The food (a mixed diet with grass silage, maize silage, soya and rapeseed meals, barley, palm oil, minerals, and molasses) was distributed at the feeding table between 0600 and 0730 h, and a robot pushed the remaining food to the feeding table every 2 h from 0300 to 1700 h. In addition, when at the AMS, the cows also received 1 to 6 kg of soya and barley (3.7 kg on average). The cows visited the AMS from 2 to 4 times a day. At 1000 and 1700 h, an employee or the farmer cleaned the cubicles while cows that were late at milking were led to the AMS (especially young cows or cows with a low milk production, which are often less motivated to eat), and those that needed a specific management intervention were picked-up and treated accordingly (insemination or administration of a medical treatment). At 0600 and 2100 h, an employee or the farmer walked among the cows for about 1 h and looked closely at the animals to detect estrus and health problems such as lameness. Signs used to detect estrus were standing to be mounted, mounting, and mucous and blood on the vulva. The time since last estrus and the cow reproductive status were used to confirm the interpretation of these signs. Cows were considered lame when their gait was affected with short striding on one or more limbs and an arched-back posture while walking and standing [score 3 on the 1–5 lameness scale from Sprecher et al. (1997)]. Foot lesions could also be detected at claw trimming. In case of lameness or foot lesions, the cows were treated by pedicure or medication. Any sign detected during these 2 systematic visits was recorded and the list was updated if more cases were found between the 2 visits. Mastitis was detected from milk conductivity assessed by the AMS; an increase of more than 25% conductivity in the milk from one quarter compared with the cow conductivity average led to an alarm to the farmer, after which the farmer further checked the appearance of the udder and the presence of flakes in the milk. The farmer kept records of all events: interventions on the herd, estrus, lameness, mastitis, accident, calving, respiratory problems, diarrhea, and so on.

Lactating cows had been fitted with CowView tags (GEA Farm Technologies, Bönen, Germany) all at the same time, 10 mo before the observations were performed, from October 2013 to February 2014. Then new cows were tagged when they joined the lactating cow groups. The tag (6 × 4.5 × 4 cm, 150 g) was fixed on a collar and maintained on top on the cow neck thanks to a 400-g counterweight (7 × 5 × 3 cm). The tag emitted radio waves within the ultra-wide band area that were detected by several antennas mounted within the barn. Cow position was determined every second by triangulation with an accuracy of less than 50 cm deviance. The accuracy was checked by adding fixed tags, by which true position in the barn is known, and measuring the deviation between what is detected by CowView and the true position. Here we inferred cow activity from this position: if the cow was found in a cubicle, it was classified as resting, if the cow was within the feed bunk zone, it was classified as feeding, otherwise it was classified as in alleys. We used the hourly accumulated activities as determined by the CowView system (i.e., time spent resting, feeding, or in alleys during each hour of the day) for 5 mo. We used data from lactating cows only. The dry cows were accommodated separately and moved to a group of lactating cows during the week after calving. The lactating cows were accommodated in 4 production pens. There were 60 to 120 cows per pen and the space allowance was 7.4 to 7.5 m^2/cow.

We first calculated the time each cow spent in each activity (resting, feeding, in alleys) per day, plus the average and standard error across days. To determine activity levels and their variations during the day, we attributed a weight to each activity according to the method proposed by Veissier et al. (2001). The weights were obtained from factorial correspondence analysis, where the observations were the hours of the day and the variables were the number of scans (across all animals and days) when each activity was detected. Before performing the factorial correspondence analysis, we removed outlier days, defined as data from a specific day and animal when the frequency of an activity was outside the 95% confidence interval [i.e., that animal spent more (or less) time on a given activity than its average ± 2 SE calculated over the previous 14 d]. We assumed that this animal encountered a disorder on that outlier day (e.g., it was diseased or some disturbance occurred in the barn). On the first axis of the factorial correspondence analysis, which summarized 93% of the variability, the 3 activities obtained the following weights: resting = −0.15; in alleys = +0.12; feeding = +0.34. This axis was considered to express level of activity. For each cow and each day, we then calculated level of activity per hour by multiplying the percentage of time spent in each activity by the weight attributed to the activity. We also calculated the average level of activity during the day [i.e., during daytime (from 0800 to 2200