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Increasing of Posture Changes as Indicator of Imminent Calving in Dairy Cows

Marisanna Speroni [1,2,*], Massimo Malacarne [2], Federico Righi [2], Piero Franceschi [2] and Andrea Summer [2]

[1] Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria, Centro di ricerca Zootecnia e Acquacoltura, 26900 Lodi, Italy
[2] Dipartimento di Scienze Medico-Veterinarie, Università di Parma, 43126 Parma, Italy; massimo.malacarne@unipr.it (M.M.); federico.righi@unipr.it (F.R.); piero.franceschi@unipr.it (P.F.); andrea.summer@unipr.it (A.S.)
* Correspondence: marisanna.speroni@crea.gov.it; Tel.: +39-0371-450126

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Abstract: The careful monitoring of cows helps minimise pain and distress during calving; moreover, knowing the exact time of birth is important to ensure timely assistance and the adequate ingestion of colostrum by the calf. However, direct visual observation is time-consuming, and the continuous presence of an observer during stage two of calving can disturb cows. Video cameras or accelerometers recording the behaviour of cows can be integrated in systems using image analysis or locomotive activity to alert the farmer as to when calving is imminent. However, alerting systems require the input of benchmark information about behaviours and changes in behaviours that can be predictive of the time of calving. Eight cows in a calving barn were continuously video-monitored. The recordings of the 24 h before delivery were analysed by instantaneous time sampling to identify the behaviours associated with an imminent birth. The same were collected in an ethogram including lying, standing, walking, turning the head towards the abdomen, eating, ruminating, drinking, sniffing the ground, allogrooming, self-grooming, and posture-changing. In our conditions, the only behaviour that was significantly influenced by the distance to delivery was posture-changing ($p < 0.0001$). Two h before the delivery, the proportion of posture changes was different from all of the hourly proportions measured from -24 to -3 h relative to delivery ($p < 0.005$), resulting in 3.6 times the average of the previous 22 h relative to delivery. An increase of posture changes may be an indicator of calving approaching, but further studies are needed to input benchmark values in alerting systems.

Keywords: calving prediction; posture changes; restlessness; dairy cows

1. Introduction

Calving is a major event in the life cycle of dairy cows. The individual monitoring of cows around the time of calving allows the early detection of difficulties or health problems and facilitates timely human intervention; it was observed that insufficient monitoring lengthened the duration of the second stage of labour [1]. The latter, together with the presentation, position, and posture of the calf is a key risk factor for perinatal mortality [1]. Therefore, the careful management of calving helps minimise pain and distress during this critical event, and prevents consequences of dystocia (difficult calving). Dystocia has been reported as one of the major causes of bovine perinatal mortality (approximately 35% at the international level) [2]. Mee et al. [3] found that calving management was the most important area of concern in herds with high perinatal mortality. Moreover, a prompt presence of caretakers at calving and the knowledge of the precise time of birth assure the provision of colostrum to calves within the first six h of life; this theoretically ensures the absorption of an adequate level of colostral immunoglobulins, which is essential for the survival of newborns. Experienced caretakers use physical and behavioural indicators to realise when a cow is close to delivery. However, direct visual observation is time-consuming, and the continuous presence of an observer during stage two of calving has been associated with an increased number of calving problems and cases of assisted delivery [4]. Automated systems are becoming widely used for milking, feeding, and detecting oestrus in dairy cows while automatic systems for monitoring calving are still scarcely used, even if many indicators and techniques are available.

Various methods have been developed to predict the calving time; some of them automatically measure physiological indicators such as body temperature [5,6], the blood levels of oestrone-sulphate and 17 beta-oestradiol [7], and the blood level of progesterone [8,9] and electrolytes in mammary secretion [10]; other systems monitoring physical indicators such as the relaxation of pelvic ligaments, physical separation of the vulva lips [11], and abdominal contractions have been proposed. According to a review from Saint-Dizier et al. [12] on methods to predict calving, measuring the relaxation of pelvic ligament and assays for circulating progesterone and oestradiol-17β are both accurate and sensitive methods to predict calving within 24 h from delivery. Moreover, the measurement of incremental daily decrease in vaginal temperature and the combination of pelvic ligament relaxation and teat-filling estimates are reliable signs to accurately predict calving within the 12–24 h from parturition. Recently, Rutten et al. [13] showed that a combination of data from sensors detecting cumulative activity, rumination activity, feeding activity, and body temperature improved the accuracy of the prediction of the time of calving process initiation, compared to a prediction based only on the date of the insemination. However, the prediction of the specific calving start time is still difficult. Overall, systems based on behavioural indicators seem the most promising, because significant changes of behaviours can be observed also within the day of calving. The main changes in behaviour before calving have been reported in the scientific literature starting from several days before delivery until the calving time, of which the most important include: searching for isolation [14], tail movements [15], aimless walking [16], turning head towards the abdomen [17], reduction of rumination time [18,19], reduction of lying time [20], sniffing the ground [16], and frequent change in the posture [21,22].

These variations in behaviour are associated with hormonal changes and uterine contractions, and are considered expressions of an overall set that is usually termed restlessness [16]. Previous evidence [14,16,17,21,22] suggests that monitoring these behaviours can provide important information on the progress of the calving process.

Video cameras or accelerometers recording the behaviour of cows can be integrated in systems using image analysis [23] or locomotive activity to alert the farmer when calving is approaching; however, alerting systems require the input of benchmark information about behaviours and changes in behaviours that can be predictive of the time of calving.

The aim of this study was to contribute to knowledge regarding the development of calving prediction systems by identifying specific behaviours that are associated with an imminent delivery.

2. Materials and Methods

2.1. Animals and Management

The animal management in this study was compliant with the current Italian law for the experimental use of farm animals (Decreto Legislativo 4 marzo 2014, n. 26).

The study was carried out at the dairy farm of the Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria (CREA) located in Cremona (Italy). The routine procedures and grouping strategies that are commonly used in the farm were applied during the study: cows were moved from the dry cow free stall to a dedicated calving pen three weeks before their expected calving date. The calving barn was a straw-bedded pen sized 16.60 m × 9 m; it was adjacent to the external paddock of the barn of the lactating cows, and was visible by cows in the calving area.

The recordings of the pre-calving behaviour of eight Italian Friesian cows that calved between 12 May 2014 and 25 July 2014 are described in this paper. Five cows were going into their second lactation (age: mean = 3.80 years; standard deviation = 0.90 years, and three cows were going in their third lactation (age: mean = 5.18 years; standard deviation = 0.57 years).

Cows were fed ad libitum once a day, approximately from 7:00 to 7:30 h; feeding operations lasted a few minutes. Bedding maintenance was done when cleaning or adding straw was needed, but at least after each new calving and within a week from the last bedding; it was generally made between 7:30 and 8:00 and lasted 10–15 mins.

Animal behaviour was video-monitored continuously by a video surveillance system located at a corner of the barn giving the best possible view of the whole barn. The equipment was a video surveillance system made by SIRZOO (Si.re.com. srl, S. Martino in Rio, Reggio Emilia, Italy) contained a fixed three-megapixel camera (3MPX Mobotix M12, Mobotix, Langmeil, Germany), twilight-controlled external infrared illuminators, and a digital recorder. The system was connected by a Wi-Fi connection system and a high speed downlink packet access (hsdpa) and hyperlan radio 5.6 Ghz to the research office building. From the same office, it was possible to remotely manage the system and record video by a personal computer (PC) recording system equipped with the Nuuo Platform.

The barn received natural light from the long side that was completely open and equipped with a feeding bunk; the other long side had three large windows so that approximately 50% of the wall was open. The short sides were closed. During the experimental period, the day length ranged from 14 h 46 min at the beginning to 14 h 58 min at the end of the study. The barn was equipped with additional artificial lights that were usually controlled by stockmen based on the practical needs, without specific patterns. A residual quantity of light remained always present in relationship to the presence of external lighting illuminating the paths inside the farms. This light was sufficient for the normal evening routine check (around 22:00) and morning supervision (around 05:00) by the caretakers.

2.2. Behavioural Observations

A provisional ethogram was created before analysing video recordings. All of the categories of behaviour expected on the basis of our experience and scientific literature were listed; then, one data recording was randomly chosen and analysed by an ad libitum sampling technique. The results of this sample analysis were used to correct the provisional ethogram, removing the behaviour that was never observed in the sample analysis. The ethogram reported in Table 1 was used to observe the behaviour of the last 24 h before delivery, considering the delivery time as the time when the calf was fully expelled. The observation was recorded by the instantaneous sampling recording rule, which is a recording rule that refers to how a behaviour is recorded. Instantaneous sampling is a recording rule in which the observer records an individual's current activity at preselected moments in time [22,23]. Starting from 24 h before the time of the delivery, short videos (five seconds) were sampled at five-minute intervals, resulting in 12 records per hour. The instantaneous recording method is not suitable to detect events or rare behaviours [24,25], thus, it was expected that urination and defecation events would not be detected accurately; when observed, they were nevertheless recorded, but these were not statistically analysed.

Table 1. Ethogram of cows housed in the calving barn.

Behaviour	Description
Lying inactive	Lying on sternum or side without performing any other described behaviour, head can be rested or raised [1]
Standing inactive	Body supported by four legs, without performing any other described behaviour [2]
Walking	Moving around the barn, not sniffing the ground
Head towards abdomen lying	Head lifted and orientated towards abdomen on stretched neck[1], lying on sternum or side
Head towards abdomen Standing	Head lifted and orientated towards abdomen on stretched neck[1], standing
Eating	Head is placed in feeding trough or over feeding trough while the cow is chewing
Ruminating lying	Jaws in the act of chewing, lying on sternum or side
Ruminating standing	Jaws in the act of chewing, standing
Drinking	Muzzle is placed in the drinking bowl [1]

Table 1. *Cont.*

Behaviour	Description
Sniffing the ground	Stretching the neck towards the ground, swinging the head
Allogrooming lying	Stretching the neck towards another cow or a calf, lying on sternum or side
Allogrooming standing	Stretching the neck towards another cow or a calf
Self-grooming lying	Biting or scratching itself using hoofs or leaning against the structures of the barn, lying
Self-grooming standing	Biting or scratching itself using hoofs or leaning against the structures of the barn, standing
Urination	Release of urine
Defecation	Release of solid waste

[1] From Jensen [17]; [2] modified from Proudfoot et al. [26].

2.3. Calculations and Statistical Analysis

The number of changes from a lying to a standing posture and vice versa (posture changes), was estimated from the information about lying and standing: if a cow was found to be in a posture different from the posture recorded five minutes before, then a change in the posture was counted.

The total number of records at which the cows exhibited each behavioural item and changes in posture were summed up for each hour relative to delivery.

The number of records of standing cows were calculated by summing records at which cows were observed standing inactive, walking, standing with head towards abdomen, eating, ruminating while standing, drinking, sniffing the ground, allogrooming while standing, self-grooming while standing, urinating, and defecating. The number of records of lying cows were calculated by summing up records in which cows were observed lying inactive, lying with head towards abdomen, ruminating while lying, allogrooming while lying, or self-grooming while lying.

Self-grooming, allogrooming and sniffing the ground were summed as “activity towards substrates”.

The number of records for each hour relative to delivery was divided by 12 in order to have results expressed as proportions of total number of records for hour. The root square of the hourly proportions of the total number of records were then arcsin transformed before statistical analysis.

The proportion of records was also calculated for the h of the day in order to graphically display the effect on behaviour of the daily farm routine and circadian rhythms.

Four cows calved during night, between 00:00 and 05:00 and four cows calved during day, between 09:00 and 19:00.

All calves and all dams were in a good health status during and after calving. Two of the eight observed cows calved with light assistance by one person without the use of mechanical traction. These two cows were kept in the dataset for the analysis because their behaviour appeared to be comparable with that of the unassisted cows, and there was no complication during or after calving. However, the occurrence of the light assistance was considered in the statistical analysis of data; one of the assisted cows calved during day, and the other calved during the night.

When possible, in behavioural studies, animals in the same pen should not be considered as an independent experimental unit because of the potential confounding effect of the social interactions. However, a large number of scientific papers reported a statistical analysis of behavioural data that considers the individual as an experimental unit, because this approach can be beneficial to answer specific research questions [18,19]. In the current study, preliminary observations and specific rearing conditions suggested that regarding investigated variables, individual cows could be considered sufficiently independent: the calving barn was sufficiently large to avoid competition for space, food, or water; moreover, few positive interactions were expected.

The number of cows in the calving barn ranged from two to five during the observation. Five calvings occurred when only two cows were present in the barn; one cow calved when two other cows were present in the barn; one cow calved when two other cows were present, and one calved when four other animals were present. The number of animals simultaneously present on the day of each calving event was considered in the statistical analysis as the main factor and its interaction with hour relative to delivery; it was not possible to test interaction with time of calving, nor assistance at calving.

The observed cows calved at eight different dates, so that the date of calving was confounded with the animal factor; it was not possible to consider the calving date as a source of variability in the statistical model.

A mixed model was used to assess whether and when (what time) any of the observed behaviours varied significantly; the hour relative to delivery was considered as a fixed factor (24 levels); also, the time of calving (two levels: night, day), assistance at calving (two levels: yes or no), and number of cows in the barn (four levels: two, three, four, five) were put in the model as fixed factors. The animal within time of calving and assistance at calving was considered as a random factor (eight levels); the interactions of hour relative to delivery with number of animals, time of calving, assistance at calving, or both were tested; only interaction with time of calving was statistically significant ($p < 0.05$) and retained in the final model. Components of variance were analysed using the MIXED procedure of the statistical analysis software SAS/STAT [27]. The denominator degrees of freedom were corrected using the Satterthwaite method. Least squares means (LSM) were compared, using the PDIFF option of LSMEANS; back-transformed LSM, and confidence limits were reported.

3. Results

Descriptive statistics were reported in Table 2.

Table 2. Descriptive statistics of proportions of total records for hour relative delivery.

Behaviour	Cows, n	Records, n/hour	Mean of Hourly Proportion	Standard Deviation of Hourly Proportion
Lying inactive	8	12	0.326	0.332
Standing inactive [1]	8	12	0.378	0.255
Walking	8	12	0.026	0.048
Head towards abdomen [1]	8	12	0.065	0.090
Eating	8	12	0.007	0.030
Ruminating [1]	8	12	0.081	0.138
Drinking	8	12	0.014	0.034
Activity towards substrates	8	12	0.091	0.073
Total lying	8	12	0.451	0.369
Total standing	8	12	0.549	0.369

[1] standing + lying.

Assistance at calving and number of cows in the calving barn didn't affect behaviour at any hour relative to delivery.

Eating, ruminating, drinking, and activity towards substrates were not affected by the hour relative to calving nor by time of calving.

The hourly proportion of posture changes was significantly affected ($p < 0.0001$) by the hour relative to delivery, even if a certain probability of interaction with the time of calving must be considered ($p = 0.0283$). Figure 1 shows the LSM for posture change.

Cows that calved at night differed ($p < 0.05$) from those that calved during the day only at −17 h, −16 h, −3 h, and −1 h relative to delivery. For both groups, two h before delivery, the proportion of records at which posture changes were observed was higher than each proportion calculated from −24 to −6 h relative to delivery ($p < 0.005$). On average, the posture changes counted at 2 h relative to delivery were 3.6 times the average of the previous h relative to delivery.

Cows that calved at night walked more than cows that calved during the day ($p = 0.0112$), but there was an interaction with hour relative to delivery. Figure 2 shows the LSM for walking (root arcsin of proportion of total records).

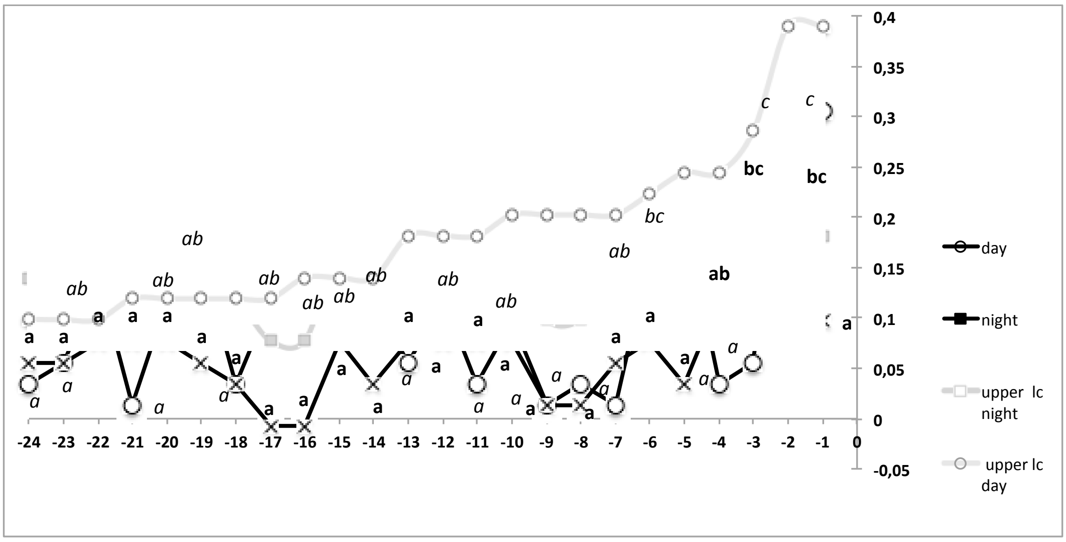

Figure 1. Least square means and upper 95% confidence limits of posture changes for cows that calved at night and by day. On the x-axis: hour relative to delivery; on the y-axis: hourly proportion of records (n/12). Different letters indicate differences ($p < 0.005$) between the least square means (LSM) within groups. Groups: cows that calved at night (**bold)** or during the day (*italic).*

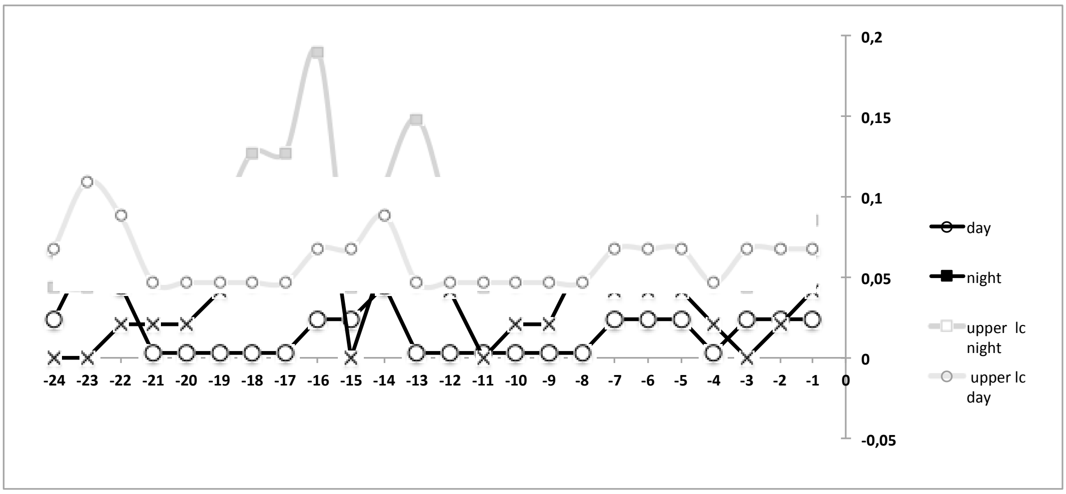

Figure 2. Least square means (LSM) and 95% upper confidence limits (cl) of walking for cows that calved at night and by day. On the x-axis: hour relative to delivery; on the y-axis: hourly proportion of records (n/12).

The variance of the proportions of records in which cows were observed lying inactive or standing inactive with their head towards their abdomen was mainly explained by the interaction between hour relative delivery and time of calving ($p < 0.05$). Also, the total lying and and total standing postures were mainly affected by the interaction between hour of relative delivery and time of calving ($p < 0.01$).

Figures 3 and 4 show the proportion of records at which cows were observed in lying and standing postures.

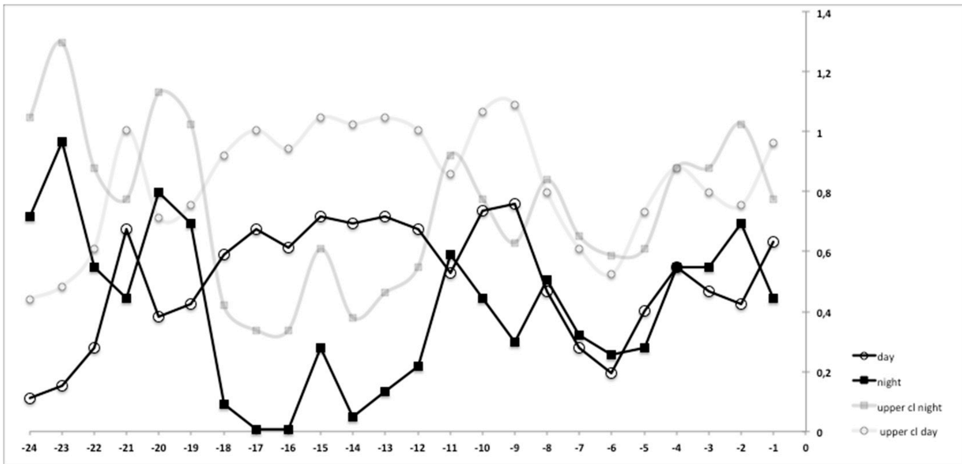

Figure 3. Least square means and upper confidence limits of lying behaviour for cows that calved at night and by day. On the x-axis: hour relative to delivery; on the y-axis: hourly proportion of records ($n/12$).

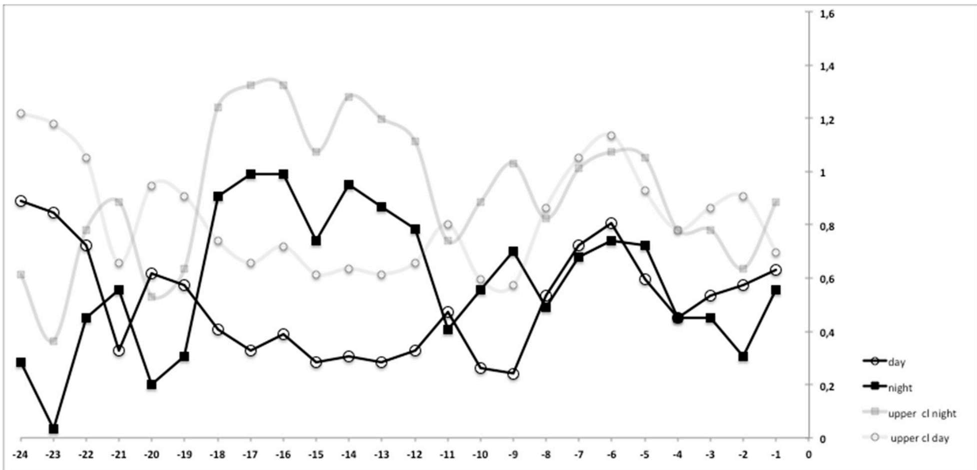

Figure 4. Least square means and upper 95% confidence limits of standing behaviour for cows that calved at night and by day. On the x-axis: hour relative to delivery; on the y-axis: hourly proportion of records ($n/12$).

Figure 5 shows the daily pattern of average proportion of records at which cows were observed in lying or standing postures.

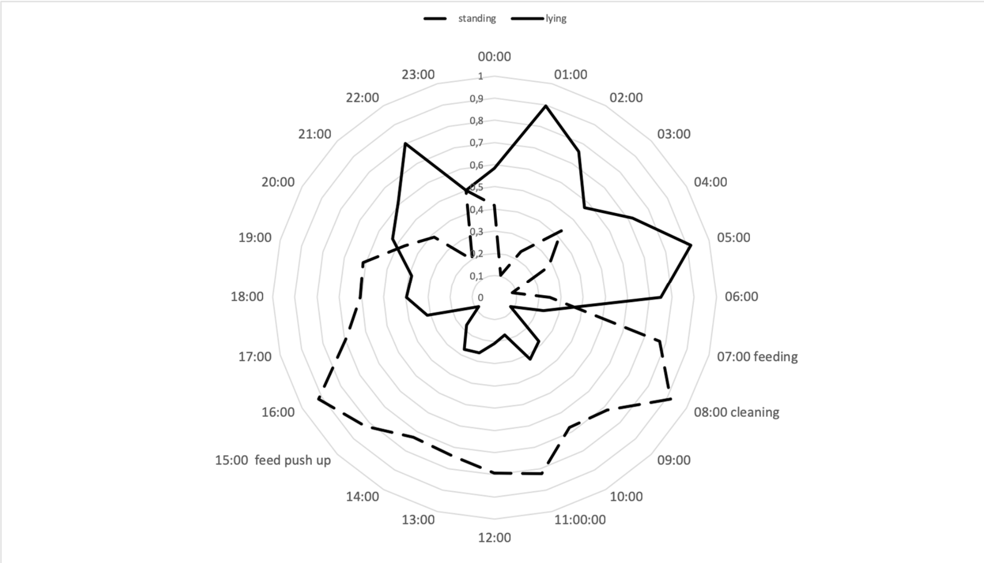

Figure 5. Means of lying and standing behaviour at h of the day.

4. Discussion

Descriptive statistics indicate that the recordings of standing, lying behavior, and posture changes were comparable with those reported by other articles [17,28].

Also, the mean proportion for walking was very similar to that observed by Miedema et al., 2011 [22] and Houwing et al., 1990 [28].

The proportion of drinking behaviour was greater than that reported by Houwing et al., 1990 [28]; activity towards the substrate is also greater when compared to the sum of what was found by these authors for similar activities; they observed 2.3% of records with cows licking objects and 1.5% of records with cows self-licking.

Eating and rumination were lower than that found by other authors [28]. We can suppose that counting for eating when a cow's head was placed in the feeding trough or over the feeding trough while the cow was chewing had excluded those part of meals when the cow's head was above or close to the feeding trough, but the chewing was not attributable with certainty. Regarding rumination, the underestimation can be explained by it not always being possible to detect the movement of the jaw when a cow could be seen only from the back.

In our conditions, the analysis of variance of proportions of rumination, eating, and drinking were not affected neither by the hour relative to delivery nor by the time of calving. However, a negative correlation between the average proportion of records at which cows were observed ruminating with the hour relative delivery ($R = -0.37$; $Rho = 0.0762$) indicated a tendency to a decrease in rumination during the day of calving: at four h before delivery was 53% of the average of all of the previous periods; at -2h, it was 40% of the average of all of the previous periods.

Significant interactions between hour to delivery and time of calving and daily pattern of standing and lying behaviours (Figures 3 and 4) suggest that circadian rhythm and managing routine Figure 5 mask or reduce the effect of approaching to deliver on other behaviours.

The animals that calved at night and those which calved during the day showed a rather complementary pattern of the lying behaviour. It is worth highlighting that this complementarity did not occurred at six h before delivery, when both groups had a drop and the number of records at which cows were observed lying overlapped.

Consistently, at six h before delivery, both groups showed an increase in standing behaviour.

The changes of posture showed a dramatic increase at two h before delivery in both groups; this peak can be considered a good indicator of the increased restlessness that is associated with uterine contractions and has been often identified by an increase in the frequency of transitions from lying to standing; such changes of posture are frequently measured as lying bouts or standing bouts [29].

The continuous recording rule is considered the gold standard for the frequency and the length a behaviour performance; however, collecting data at fixed time intervals (instantaneous sampling) is a labour-saving alternative method to improve the efficiency of data collection. According to numerous authors, instantaneous sampling with an interval length of 10–15 min is a suitable recording method to estimate the proportion of time spent lying by cattle [30–34]. Therefore, we assumed that the number of posture changes that we estimated from recording behaviour by instantaneous sampling every five minutes was a good estimator of the actual number of transitions in posture, and therefore of the number of lying bouts.

Chen et al. [35] compared the instantaneous sampling and continuous observation of dairy cattle; they found that the amount of time spent lying was accurately captured using sample intervals $\leq$ 30 min. Concerning the number of lying bouts, they found that a sampling interval of five minutes produced data strongly related to those obtained by continuous observation, but with a certain degree of underestimation; moreover, the study showed that a sample interval $\leq$ 3 min accurately estimated the number of lying bouts. Having used a sample interval of five minutes, a slight underestimation of posture changes was possible in our study.

The average of the number of posture changes totally recorded across the 24 h before calving in the current study was 26.75 (standard deviation: 8.97 times/day). Similar frequencies of standing bouts and lying bouts have been reported in literature [19,20]; this figure is about twice the average values of lying bouts recorded by a previous study [36] in the control periods (first, sixth and 12th weeks of lactation). According to Miedema et al. [22], the average lying bouts observed in the pre-calving control period ($-1 \div -10$ days relative to calving, median = -3) was 16.4 $\pm$ 4.8 times/day.

The peak of posture changes at two h before calving is partially in agreement with results from Jensen [17] of video-recorded cows housed in individual pens. The latter found the increase in frequency of lying bouts starting at -4 h relative to calving, and hourly average lying bouts at -2 h relative to calving being 2.2 times the average of frequency observed from -12 h relative to calving. Similarly, in our study, the frequency of posture changes at -2 h was 2.8 times the average from -12 h; also, Miedema et al. [22] reported an increase in the frequency of lying bouts starting at approximately four h and 13 min before calving. Comparing assisted and unassisted calvings, the same authors [37] reported that lying frequency increased from -6 h relative to calving in unassisted animals, but only during the final two h before calving in assisted animals.

5. Conclusions

Taking into account the results obtained in this study and others, we can conclude that the increase in the frequency of posture changes may be a very useful indicator in identifying cows that are close to delivery. This type of data can be collected automatically via accelerometers, attached to the animal's leg or worn around the neck, making their use very effective.

Systems that are currently used for oestrus detection could be implemented also for calving prediction [38]. Further studies are needed to define the benchmark increase in lying bouts frequency to be used in alerting systems.

Moreover, the higher number of posture changes observed in 24 h before calving confirms the need to pay great attention to the comfort of the calving barns.

Author Contributions: M.S. designed the experiment; each author has made substantial contributions to the acquisition, analysis and interpretation of data; all authors collaborated in writing the manuscript; furthermore, each author has approved the submitted version and agrees for ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated, resolved, and documented in the literature.

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