Changes in lying behavior of pre-partum dairy cows

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ABSTRACT

The transition period is the most critical time in the lactation cycle of dairy cows. Transition cows experience many physiological and nutritional changes before and after calving. An automated device that predicts the onset of parturition could potentially minimize the effect of dystocias by enabling farmers to intervene early. This study is aimed to investigate changes in lying behavior of pre-partum dairy cows, measured by a new type of pedometers. The ultimate aim is to predict calving time with these changes in lying behavior.

Only included in this study are 254 healthy dairy cows with normal spontaneous parturition which the exact time of parturition is known. For number of lying bouts, duration of lying bouts and daily lying time, data of the last 28 days prior to calving is used. For lying time per two hours only data of the last 7 days prior to calving is used.

This study shows the last day before calving a significant decrease in average length of lying bouts ($p=0.00$) and total daily lying time ($p=0.00$) compared with the previous five days. Last day before calving the daily number of lying bouts appears to increase, but it was not significant ($p=0.072$). In addition, lying time per two hours data shows a circadian rhythm. This circadian rhythm of these dairy cows is clearly visible until the last day before calving.

In conclusion, it is clear that significant changes of length of lying bouts and total daily lying time indicate the imminent parturition. For predicting the moment of birth with lying time, the change of circadian rhythm the last day prior to calving needs further research. Electronic data loggers could be useful as predictors of calving time. The use of changes in lying behavior as indicators of imminent calving deserves further research, both for daily data as two-hour data.

INTRODUCTION

The transition period is the most critical time in the lactation cycle of dairy cows. Transition cows experience many physiological and nutritional changes before and after calving. They are susceptible to a large number of diseases and infections during this period (Huzzey, Keyserlingk, M. A. G. von *et al.* 2005). In the calving pen, supervision is needed in order to help the cow when necessary. Poor calving management would have significant negative effects. Between 7 and 8 percent of all calves are stillborn (USDA 2007). Approximately half of calves born to heifers (51.2%) and 29.4% of calves born to multiparous cows were delivered with human assistance, whereas 18.9% and 6.9% for respectively heifers and multiparous cows were classified as severe dystocia (Lombard, Garry *et al.* 2007). Dystocia causes significant losses in milk yield, in addition dystocia has negative effects on fertility (Dematawena, Berger 1997). This information shows the importance of minimizing problems around calving.

The number of cows per farm is growing in Europe. When the number of cows per farm worker increases, they have less time to spend per cow. In addition, professional farm workers are difficult to find and the labor is expensive compared to the price of milk (Raussi 2003). An accurate prediction of time of birth could make it possible to provide better care and management, so that health problems and calving difficulties can be avoided as early as possible (Felton, Colazo *et al.* 2013). An automatic monitoring system that could predict this moment could be very useful.

Several hormonal changes cause changes of behavior during late pregnancy. Maturation of the hypothalamic-pituitary-adrenal axis is an important process during fetal life. Fetal cortisol contributes to the trigger mechanism, which result in calving (Challis, Sloboda *et al.* 2001). In addition, estrogen levels in maternal blood increase a few days before parturition. These increased estrogen levels cause behavioral changes (Kindahl 2004). Several reports describe the behavioral aspects of calving in dairy cows. Changes in behavior during the last couple of days before calving, such as ruminating, grooming, drinking and eating, indicate that time of calving is near (Huzzey, Veira *et al.* 2007). On the day of calving the cow increasingly separates herself from the herd, but only when the stocking density is lower than one cow per hectare (Lidfors, Moran *et al.* 1994). Proudfoot *et al.* (2014) found that pre-partum dairy cows housed in individual maternity pens preferentially use a secluded area to calve.

New technologies for health monitoring are being developed. Automated systems are increasingly used for feeding, milking and detecting estrus in dairy cattle. Maltz and Antler (2007) examined the number of steps, number of lying bouts and lying time seven days prior to calving. They found a significant decrease in lying time the day before calving compared to 2-7 days before calving. Miedema and Cockram *et al.* (2011a) investigated with video cameras the behavior of twenty Holstein-Friesian cows during the last 24 hours before normal calving compared with a control group Holstein-Friesian cows in late gestation. They found increased numbers of tail raising and lying bouts in the final six-hour period before birth of the calf. Jensen (2012) found cows were more active, had more lying bouts and spent less time lying during the final 24 hours before expulsion compared to 2-4 days before calving. All these papers indicate a change of behavior to imminent calving.

AIM OF THE STUDY

The aim of this study is to investigate changes in lying behavior (number of lying bouts, average length of lying bouts and lying time) of pre-partum dairy cows, measured by a new type of pedometers. The ultimate aim is to predict calving time with these changes in lying behavior.

MATERIALS AND METHODS

Housing and animals

Our data are part of a large study monitoring cows in the period around parturition. This study is set up by Nedap, Vetvice, Utrecht University and Wageningen University and Research Centre provided a huge set of data. Nedap is a technology company present in different markets. Their Livestock Management department offers barn automation based on individual animal identification that identifies monitors and helps the farmer look after animals individually (Nedap 2016). Vetvice is a Dutch veterinary consultancy firm that delivers practical information on dairy cow housing and husbandry to dairy farmers. Their aim is to maximize the health and welfare of animals and man alike while guaranteeing cost-effective production of top-quality food products (Vetvice 2016).

The data so far, has been collected at eighteen different farms in the Netherlands and data collection is still going on. In order to obtain reliable data which can be used on farms in practice, a range of farms has been incorporated in this study. All farms are free-stalls with an average of 150 dairy cows per farm located throughout different provinces in the Netherlands. Half of these eighteen farms use automatic milking systems and the other nine farms use conventional milking parlors. All farms use calving pens with straw bedding. The cows from all eighteen farms are monitored during a timeframe of six weeks before calving to four weeks after calving. For this study only data of lying behavior during the last 28 days prior to calving is used.

Calving management

A calving form is created so that farmers can administrate information from each cow. They are asked to fill in this paperwork which state the time and type of parturition, calving signals and time of these calving signals and time of afterbirth. In addition diseases and other abnormalities are asked to be written on that sheet. Calving signals were scored on a 6 point scale: (1) broad pelvic ligament relaxation, (2) restlessness and tail rising, (3) laying and uterus contractions, (4) amnion sac visible, (5) limbs visible, and (6) the calf was born and no signs were seen. The ease of calving was scored on a 5 point scale: (1) easy without human assistance, (2) easy with moderate traction, (3) difficult with considerable traction, (4) difficult with usage of calf puller and (5) requiring veterinary assistance. Students collect every eight weeks these sheets describing the calving event. These data are entered in Microsoft Excel. When a farmer is not sure about the exact time of calving he makes an estimate.

Electronic data logger

The used pedometers measure the number of paces and the number of lying bouts the cow makes with the help of a G-sensor (Nedap 2016). The pedometer stores data per fifteen minutes and can save information up to a limit of twenty-four hours storage. An antenna is placed in the barn, which receives this data from the sensor. In conclusion cows can go outside during night or day without loss of information, provided that each cow comes to the barn at least once a day. The antenna sends all data to the computer program Velos®. Velos® is a software program that can be linked to farm management programs like Veemanger®, T4C® or Agrovision®. Data for individual cows are presented to the farmer as amount of activity per two hour period. This new sensor uses the acceleration as measure of movement and x-, y-, and z-axis (three-dimensional space) to determine the angle towards the floor. From this angle the positioning of the sensor is determined and in combination with the movement a distinction can be made between standing-, lying-, or walking activity. Lying bouts will be derived from lying time per fifteen minutes data. Minimum time of a lying bout is defined to be fifteen minutes. If the time between a lying period, and the next lying period (time standing or walking) is less than fifteen minutes, both lying periods will be counted as one and the same lying bout. At time of writing, the pedometer has not been validated.

Data refinement

Each cow is measured from 42 days before calving until 28 days after calving. The data of all cows (at this moment approximately 2000) is collected in a database. The data used for this study has been collected from March 2014 to November 2015. For number of lying bouts, duration of lying bouts and daily lying time, only data of the last 28 days prior to calving is used. For lying time per two hours only data of the last 7 days prior to calving is used.

Four farms were excluded, due to lack of reliable information provided by the farmers during the whole period. Cows of which the data is not useful are also excluded. Firstly, all cows were assessed whether their exact time of calving was known. For this study it is very important to have reliable calving time data. Cows are excluded when the time of birth was not known or it was an estimate. Secondly only cows that calved easy without human assistance (calving type 1) have been selected for this research. Two papers described that dairy cows with dystocia transitioned from standing to lying position more frequently than cows without dystocia beginning twenty-four hours before parturition (Proudfoot, Huzzey *et al.* 2009, Ito, von Keyserlingk *et al.* 2010). The next step was eliminating cows with illness or lameness during transition period. These illness included cows showing stillbirth, abortion, milk fever, retention secundinarum and mastitis. Several researchers described that lameness is associated with high lying times, long lying bouts and variability in the duration of lying bouts (Brzozowska, Łukaszewicz *et al.* 2014, Ito, von Keyserlingk *et al.* 2010). This means that lameness influences lying behavior of dairy cows. The initial setup of this study did not include information of parity, but in most studies a distinction was made between heifers and multiparous cow. Heifers and multiparous cows show different types of behavior (Felton, Colazo *et al.* 2013). The parity of most cows is obtained from Velos®. The cows without information of parity are excluded. In last step cows with inconsistency between farmers management and paperwork are excluded. Only included in this study are healthy dairy cows with normal spontaneous parturition which the exact time of parturition is known. The

original database included approximately 2000 cows but after this refinement, it provided usable information of 254 healthy cows received from fourteen farms.

All different types of data are collected in Microsoft Excel. Time of birth is for all data synchronized to moment zero. This study included two ways of evaluation: first lying behavior per day, according to literature. These data contains number of lying bouts per day, average length of lying bouts and total daily lying time. Brzozowska and Łukaszewicz *et al.* (2014) showed differences in locomotor activity between heifers, second lactation cows and older cows. Therefore, in this study cows are distributed over three lactation groups: (1) heifers (n=20); (2) second lactation cows (n=87) and (3) three- or more lactation cows (n=147). Most previous studies show daily lying time in hours per day (Miedema, Cockram *et al.* 2011a, Lobeck-Luchterhand, Silva *et al.* 2015), therefore, data of lying time in present study is converted from minutes to hours per day.

The second way of evaluation is lying time per two hours because this is how data are presented to the farmer in the management system. For this evaluation all cows are divided into twelve groups based on time of parturition. Group 1 consist of cows which have calved between 00.00 and 02.00 o'clock, group 2 consist of cows which have calved between 02.00 and 04.00 o'clock, etc. up to group 12.

Statistical analysis

Differences in number of lying bouts, duration of lying bouts and daily lying time between day one ante partum and the control days were tested using linear mixed models in SPSS. The same is done between two days ante partum and the control days. Every individual cow has her own control period. This period is the previous five days, so the control values are the average number of lying bouts, average length of lying bouts and the average daily lying time of this control period. This means that day -2 will be compared with the average of day -3 until -7 and day -1 will be compared with the average of day -2 until -6. The different farms were designed as a random effect. Additionally, the three different parity groups (heifers, second lactation and older cows) are included as fixed effects. In total, six tests were performed whereby a Bonferroni correction is applied. Factors were declared significant at $P \leq 0.05$

Analysis of lying time per two hours, was only performed in the three groups with the most animals. The size of the other groups was too small to be reliable. Group 6 and group 10 contain 30 cows and group 8 contains 35 cows. Lying time per two hours was tested using linear mixed models in SPSS. The last three periods of two hours before calving were compared with the control values of these three periods. The control value of a period is an average of five identical periods of two hours in the previous days. In this way, management factors and day-night rhythm are taken into account. Different farms were designed as a random effect. In total, nine tests were performed and a Bonferroni correction is applied. Factors were declared significant at $P \leq 0.05$.

RESULTS

Lying bouts

Results are obtained from 20 heifers, 87 second parity cows and 147 older cows. An increase in lying bouts is seen during transition period (Fig. 1). During the last day before calving the number of lying bouts increases from 7.5 ± 1.7, the average of the previous 5 days, to 7.7 ± 2.5. This increase is not significant both for one and two days before parturition compared with their control periods (Table 1A-1B). All three parity groups show an increase in daily lying bouts to imminent calving (Fig 1.), however the difference in increase between the three parity groups was not significant (Table 2). Therefore the analysis of one day before parturition is repeated without parity as fixed effect. The increase found in this analysis had a mean of 0.50 ± 0.17 lying bouts. As reported above, after Bonferroni correction this increase in number of lying bouts also is not significant (p=0.072).

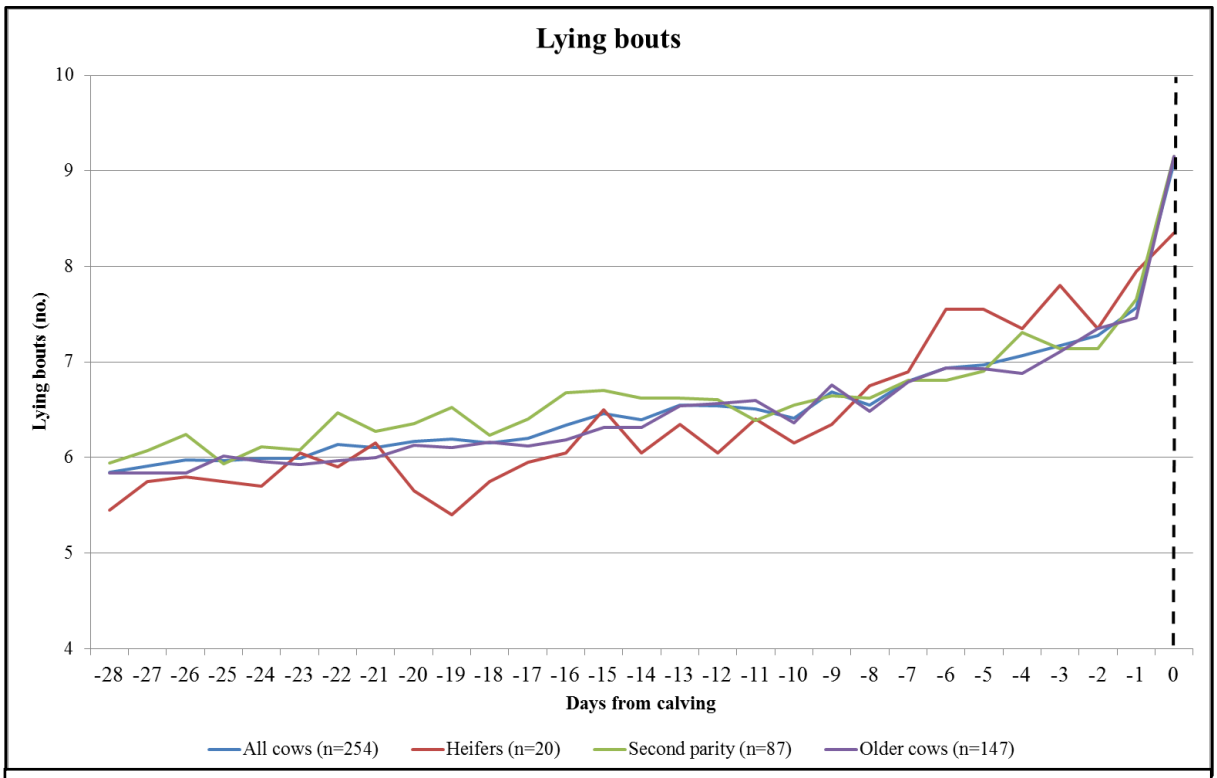

Figure 1: The increasing number of lying bouts from day 28 before up to calving (n=254). The dotted line shows calving day.

Duration of lying bouts

Results are obtained from 20 heifers, 87 second parity cows and 147 older cows. A decrease in average duration of lying bouts is seen during the transition period (Fig. 2). This decrease is not significant two days before parturition compared with the control period (Table 1A). Last day before calving the average length of lying bouts decreases from 118 ± 37 minutes to 100 ± 46 minutes, this decrease is significant (p=0.000) and is shown in Table 1B. This means that last day before calving the average length of a lying bouts significant decreases compared with the average of the previous five days. Figure 2 show a faster decrease for heifers compared with multiparous cows, but differences between the three parity groups were not significant (Table 2). Therefore the analysis of one day before parturition is repeated without parity as fixed effect. The decrease found in this analysis had a mean of 18.4 ± 3.02 minutes and was significant (p = 0.00).

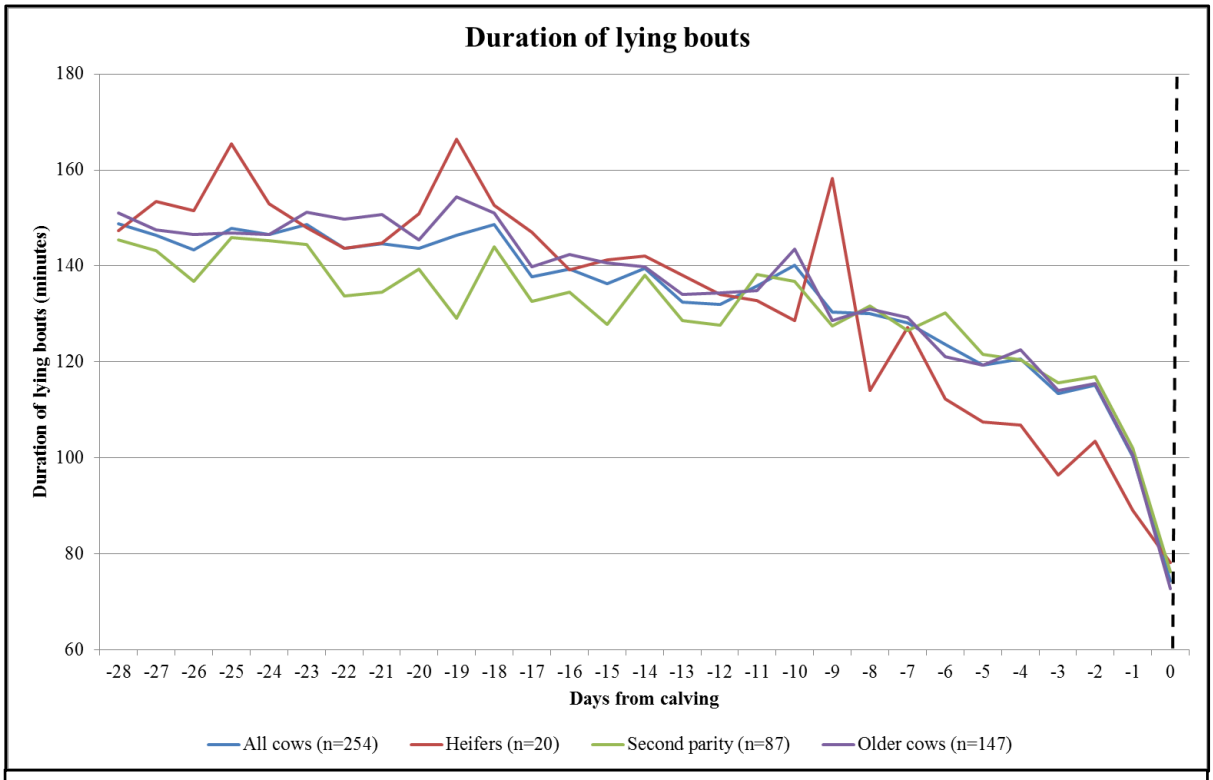

Figure 2: The decreasing duration of lying bouts from day 28 up to calving (n=254). The dotted line shows calving day.

Lying time per day

Results are obtained from 20 heifers, 87 second parity cows and 147 older cows. A decrease in total daily lying time is seen during the transition period (Fig. 3). This decrease is not significant two days before parturition compared with the control period (Table 1A). The last day before calving total daily lying time decreases from 12.7 ± 2.5 hours to 11.4 ± 3.2 hours, this decrease is significant (p=0.000) and is shown in Table 1B. This means that the last day before calving total daily lying time significant decreases compared with the average of the previous five days. Figure 3 show a lower daily lying time for heifers compared to multiparous cows, but differences between the three parity groups were not significant (Table 2). Therefore the analysis of one day before parturition is repeated without parity as fixed effect. The decrease found in this analysis had a mean of 1.27 ± 0.15 hours and was significant (p=0.00).

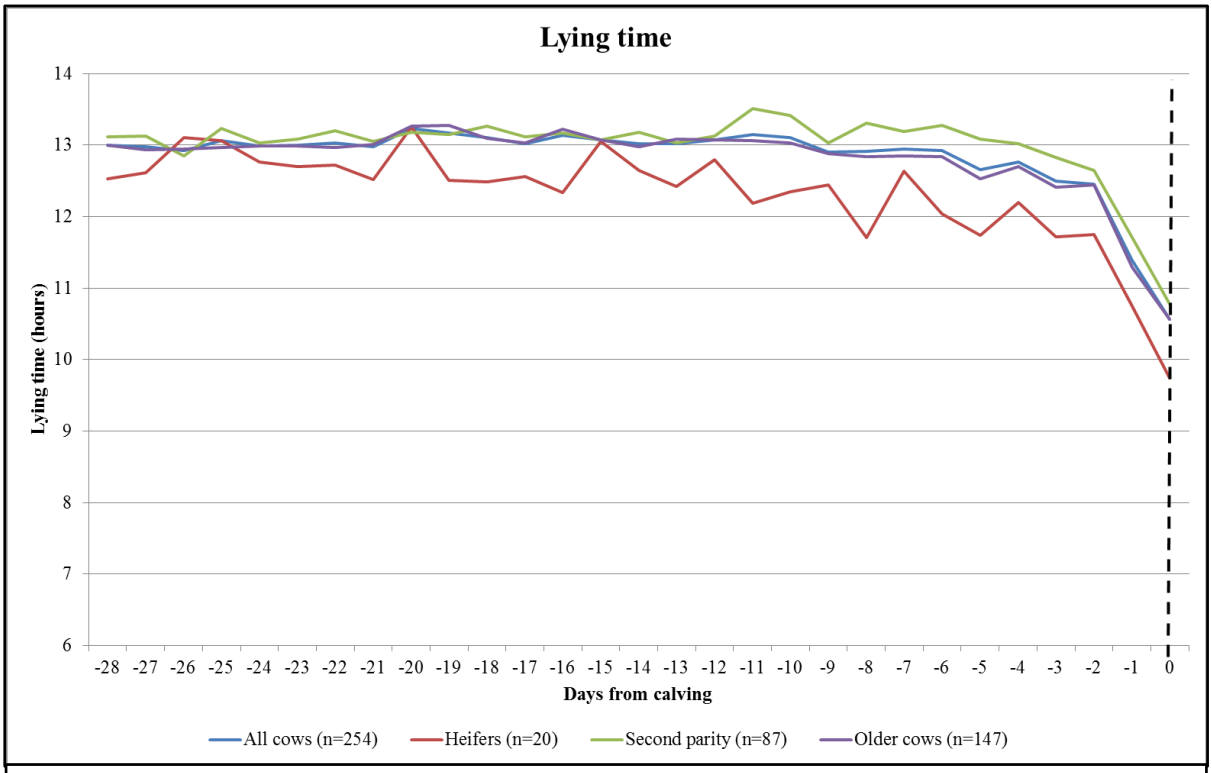

Figure 3: The decreasing daily lying time from day 28 before up to calving (n=254). The dotted line shows calving day.

Lying time per 2 hours

All cows are divided in calving time groups as described above. Figure 4, 5 and 6 show graphs of three groups dairy cows which calved between respectively 10.00 until 12.00 am, 14.00 until 16.00 pm and 18.00 until 20.00 pm. The three figures show a comparable circadian rhythm. This circadian rhythm of these dairy cows is clearly visible until the last day before calving. It seems like an absence of the peak of lying time during the last twenty-four hours before calving. The last three two-hour-intervals before calving were compared with the average of these moments on the previous five days. The results are shown in Table 3A-3C. No significance is shown for the last two hours prior to calving compared with the average of these 2 hours of the previous 5 days. The interval before, 4 until 2 hours prior to calving, shows significance (p=0.036) for group 6 only. The interval from 6 to 4 hours prior to calving shows significance both for group 6 (p=0.009) as group 8 (p=0.009) but not for group 10.

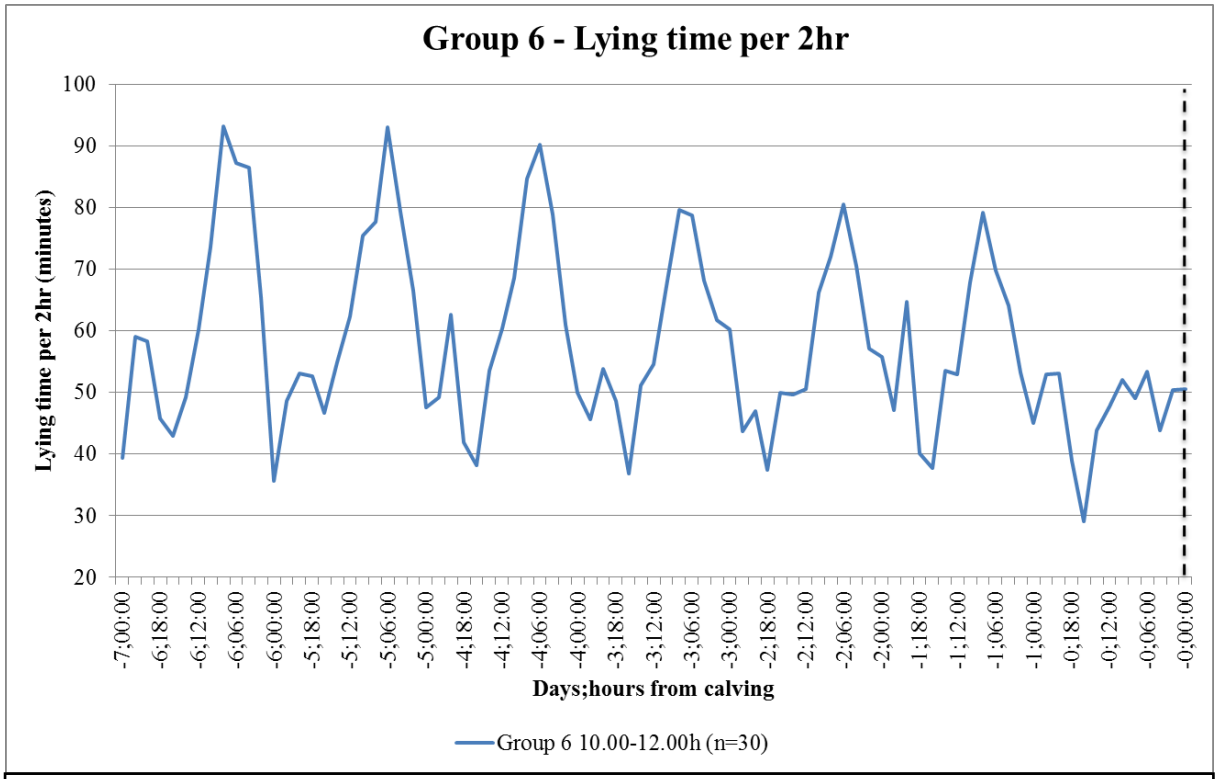

Figure 4: Lying time per two hours (blue line) of group 6 from day 7 before up to time of parturition. Cows from group 6 (n=30) have calved between 10.00 and 12.00 am. The dotted line shows time of birth.

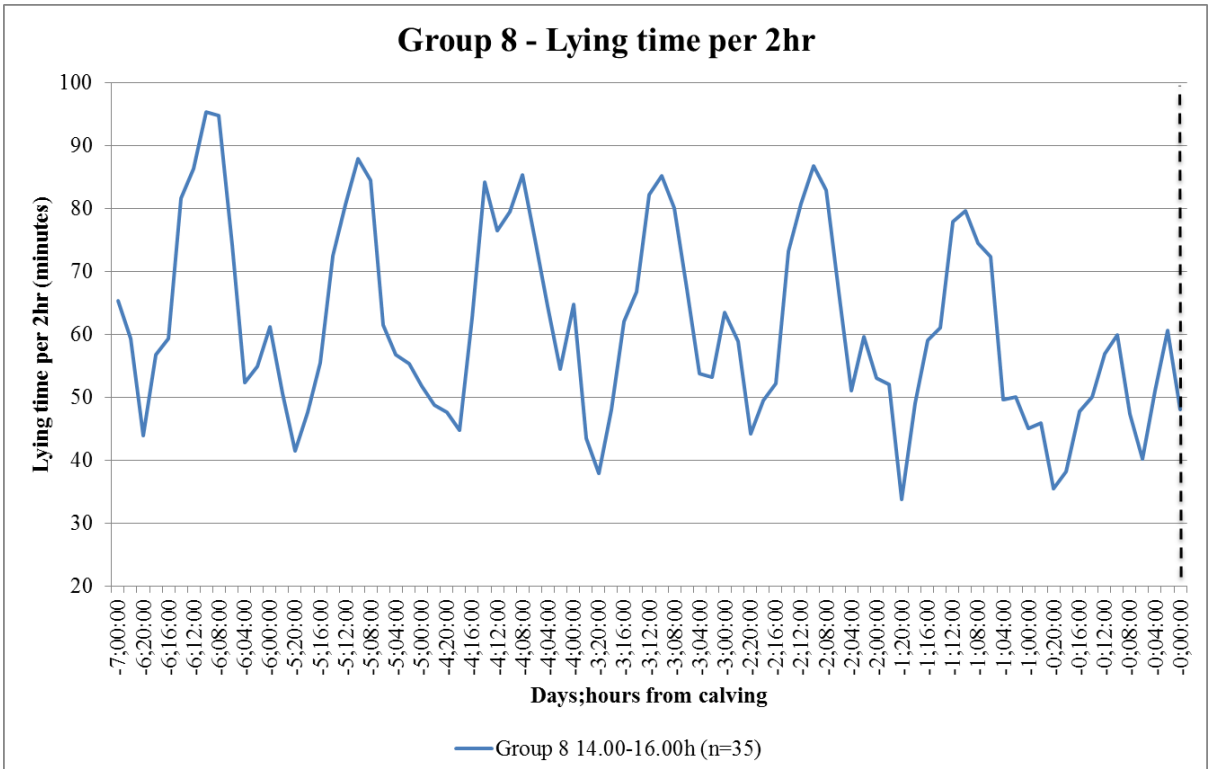

Figure 5: Lying time per two hours (blue line) of group 8 from day 7 before up to time of parturition. Cows from group 8 (n=35) have calved between 14.00 and 16.00 pm. The dotted line shows time of birth.

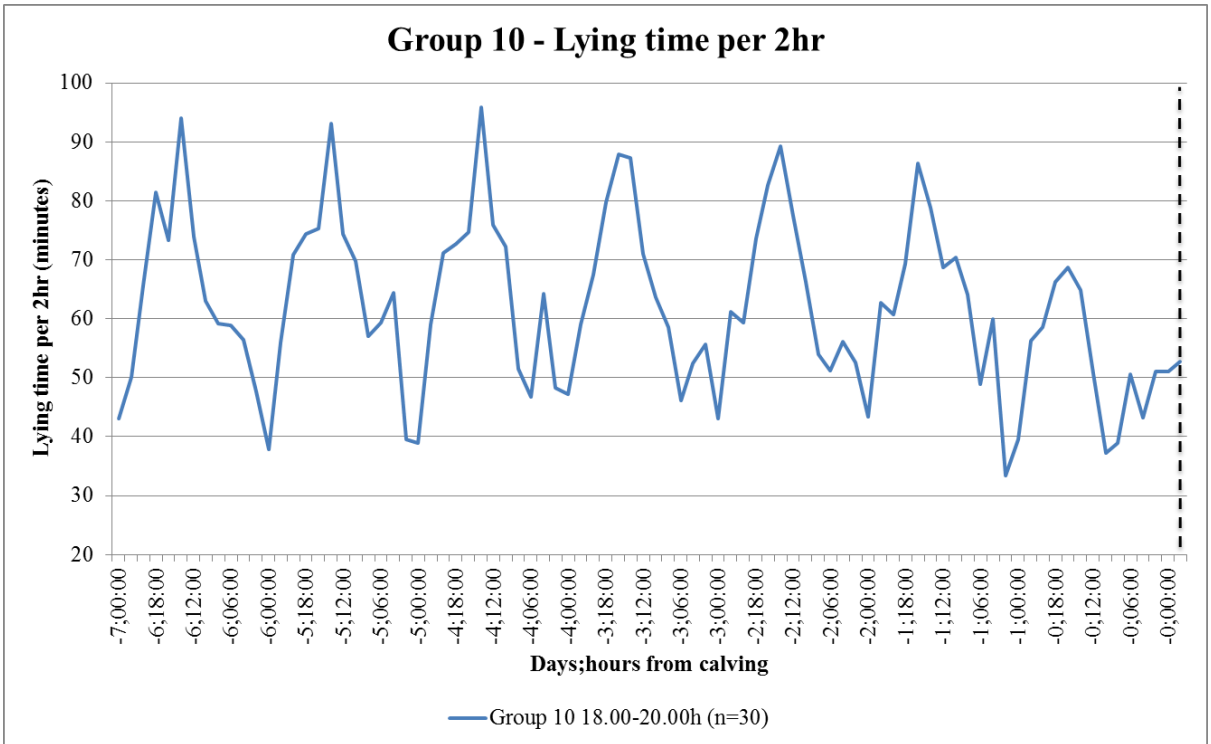

Figure 6: Lying time per two hours (blue line) of group 10 from day 7 before up to time of parturition. Cows from group 10 (n=30) have calved between 18.00 and 20.00 pm. The dotted line shows time of birth.

Table 1A. Summary of the mean (±S.D.) daily numbers and durations of lying behaviours during the control periods and day two ante-partum, with the P-value of the difference between them. Data from 254 healthy cows from 14 farms. *Bonferroni corrected.

Behaviour	Control value	Day -2	P-value
Lying bouts (no.)	7.0 ± 1.7	7.3 ± 2.2	0.298
Duration of bouts (min)	121 ± 38	115 ± 49	0.077
Lying time (hr)	12.8 ± 2.5	12.4 ± 3.0	0.052

Table 1B. Summary of the mean (±S.D.) daily numbers and durations of lying behaviours during the control periods and day one ante-partum, with the P-value of the difference between them. Data from 254 healthy cows from 14 farms. *Bonferroni corrected.

Behaviour	Control value	Day -1	P-value
Lying bouts (no.)	7.5 ± 1.7	7.7 ± 2.5	0.072*
Duration of bouts (min)	118 ± 37	100 ± 46	0.000*
Lying time (hr)	12.7 ± 2.5	11.4 ± 3.2	0.000*

Table 2. Summary of the mean (±S.E.) differences in number of lying bouts, duration of lying bouts and lying time of the three different parity groups during the control periods and day one ante-partum, with the P-values of the differences between these three parity groups.

	Lying Bouts		Duration of Lying Bouts		Lying time	
	Mean ± S.E.	P-value	Mean ± S.E.	P-value	Mean ± S.E.	P-value
Older cows - Intercept	0.458 ± 0.201	0.033	18.3 ± 3.9	0.000	77.5 ± 11.6	
Heifers	0.463 ± 0.483	0.991	16.2 ± 11.3	0.852	68.5 ± 33.6	0.788
Second parity	0.585 ± 0.268	0.635	18.9 ± 6.0	0.916	75.6 ± 19.1	0.920

Table 3A. Summary of the mean (± S.D.) lying time per two hours during control period and the last two hours before calving, with the p-value of the difference between them. Cows from group 6 have calved between 10.00-12.00 am, cows from group 8 between 14.00-16.00 pm and cows from group 10 between 18.00-20.00 pm. *Bonferroni corrected.

	Control value	-0.00 until -0.02	P-value
Group 6 (n=30)	60 ± 32	50 ± 28	0.183
Group 8 (n=35)	55 ± 21	61 ± 22	0.172
Group 10 (n=30)	51 ± 33	46 ± 21	0.830

Table 3B. Summary of the mean (± S.D.) lying time per two hours during control period and 4 until 2 hours before calving, with the p-value of the difference between them. Cows from group 6 have calved between 10.00-12.00 am, cows from group 8 between 14.00-16.00 pm and cows from group 10 between 18.00-20.00 pm. *Bonferroni corrected.

	Control value	-0.02 until -0.04	P-value*
Group 6 (n=30)	72 ± 26	44 ± 35	0.036*
Group 8 (n=35)	55 ± 17	51 ± 34	0.348
Group 10 (n=30)	43 ± 33	59 ± 16	0.063*

Table 3C. Summary of the mean (± S.D.) lying time per two hours during control period and 6 until 4 hours before calving, with the p-value of the difference between them. Cows from group 6 have calved between 10.00-12.00 am, cows from group 8 between 14.00-16.00 pm and cows from group 10 between 18.00-20.00 pm. *Bonferroni corrected.

	Control value	-0.04 until -0.06	P-value
Group 6 (n=30)	82 ± 21	53 ± 35	0.009*
Group 8 (n=35)	69 ± 23	40 ± 30	0.009*
Group 10 (n=30)	51 ± 38	50 ± 25	0.830

DISCUSSION

Influence of parity

This research didn't found difference in lying behavior between heifers, second parity cows and older cows. Several papers describe significant difference in locomotor activity between heifers and multiparous cows (Brzozowska, Łukaszewicz *et al.* 2014). Present research shows that these differences do not apply for lying behavior between. However, Georg and Beintmann *et al.* (2008) showed that one day before calving heifers lay two hours less than multiparous cows. As in this study, they found no significance in duration of lying periods between heifers and multiparous cows. Recent research by Lobeck-Luchterhand and Silva *et al.* (2015) shows that heifers spent less time lying per day and had shorter lying bout durations than multiparous cows. As the study of Jensen (2012), in present research no significant differences in lying behavior between heifers and multiparous dairy cows were found. It should be mentioned that in this research the parity group 'heifers' consists only 20 animals, compared to 87 second parity cows and 147 older cows. The studies described above show all different results between different parities, this indicate that further research to lying behavior and the influence of different parities is required.

Circadian rhythm

Using the two hour data, the present study show a circadian pattern for lying time up to day 1 before parturition. The last day before calving lying time patterns differs from the normal circadian rhythm. Present study is the first who described these change in diurnal pattern the last day prior to calving. Most studies evaluated lying time in lactating dairy cows, and not during pre-partum period. Fregonesi and Tucker *et al.* (2007) reported that lactating dairy cattle spend twelve to thirteen hours per day lying down, furthermore dairy cows have a higher priority for lying than eating (Munksgaard, Jensen *et al.* 2005). Previous studies show that diurnal patterns of lying behavior for dry cows are similar to that for lactating dairy cows (Schirmann, Chapinal *et al.* 2012, Fregonesi, Tucker *et al.* 2007). These behavioral change needs further research. Also other behavior patterns, such as eating time (Schoemaker 2016) and step-activity (Frieling 2016) show in pre-partum dairy cows similar circadian patterns. In order to predict time of birth the different circadian patterns need to be included in the evaluation.

Variation in cows and farms

In this study data from cows with dystocia is not used. Proudfoot and Huzzey *et al.* (2009) described that dairy cows with dystocia transitioned from standing to lying position more frequently than cows without dystocia beginning twenty-four hours before parturition. This increased unrest could be possibly detected with the pedometers used in this study. This information suggests that an imminent parturition of a dystocia cow can be detected easier than a normal parturition. May be it is possible to detect dystocia cows earlier. These questions to the influence of dystocia need further research.

Figures 1-6 shows different lying behaviors, these are all averages of many cows. Figure 7 shows daily number of lying bouts of five different second parity cows from the same farm. This figure shows a wide variation between the different cows. For example, the patterns of cow 2 (red line) and cow 3 (green line) are completely different.

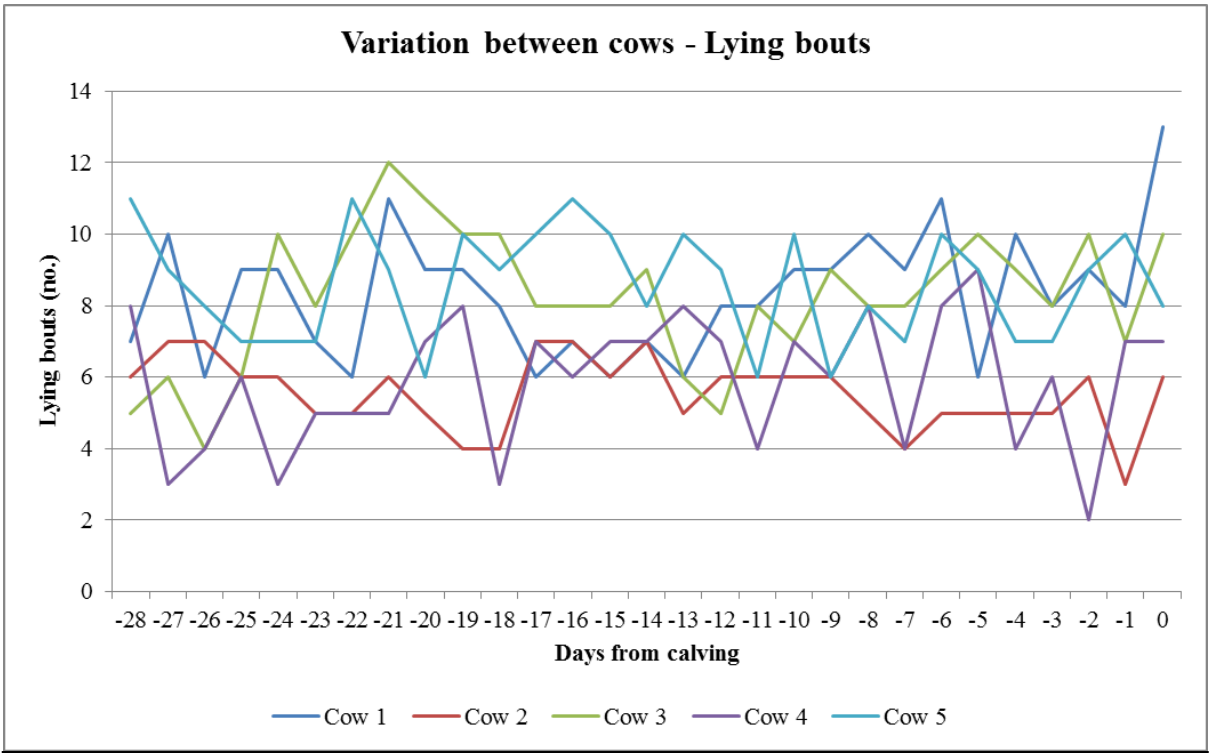

Figure 7: Variation in daily number of lying bouts between five second parity cows of the same farm.

This variation makes it impossible to compare a cow with other cows. Variation between cows is also seen in 'duration of lying bouts', 'daily lying time' and 'lying time per two hours'. Because of this for statistical analysis is chosen to compare data of a single cow with a control period of the same cow. In this way, variation between cows can not affect the results.

Farm management can influence the way how dairy cows use of a barn and lying area. Behavior may be affected if there are more cows than resting boxes, because lying at the same time is impossible for all cows. Overstocking free-stall barns is an option for enhancing returns of investments (Bewley, Palmer *et al.* 2001). A study of Wierenga and Hopster (1990) showed that overcrowding free-stalls reduces lying time. Other studies have shown when competition in the pen increased, daily lying time decreased (Fregonesi, Tucker *et al.* 2007) and standing time increased (Huzzey, DeVries *et al.* 2006). For present study data of pre-partum dairy cows from fourteen different farms is used. Differences between farms, such as feeding time, size of calving pens and overcrowding, can influence data. In this study there was no overcrowding. For further research it could be useful to make difference between the different farms, at which farm insecurities can be avoided.

Usefulness

This study showed significant changes of daily lying time and average length of lying bouts during the last day before parturition, in comparison to the control period during late pregnancy. However, no significant increase in number of lying bouts one day prior to calving compared with the previous five days was found (7.7 ± 2.5 versus 7.5 ± 1.7). This

result is lower than measured in other studies (Miedema, Cockram *et al.* 2011a, Jensen 2012). Miedema and Cockram *et al.* (2011a) found with use of video cameras a significant increase in number of lying bouts compared with the average of the previous ten days (24.2 ± 6.8 versus 16.4 ± 4.8). They defined a lying bout as a period of lying, separated by periods of standing or walking. The difference of the mean ± standard deviation between these two researches is enormously. An explanation for the different results in our study could be explained by the different methods for measuring lying bouts. The pedometers used in the present study only register a lying bout when cows lie for at least fifteen minutes. If the time between a lying period, and the next lying period (time standing or walking) is less than fifteen minutes, both lying periods will be counted as one and the same lying bout (Nedap 2016). This way of measuring influence the number of lying bouts, whereby a lower number of lying bouts will be found. Several researches describe restless behavior whereby significant increases in lying bouts were found (Miedema, Cockram *et al*. 2011a, Miedema, Cockram *et al*. 2011b, Owens, Edey *et al.* 1985, Titler, Maquivar *et al*. 2015, Jensen 2012). Increased restlessness prior to calving is possibly a result of discomfort associated with hormonal, physiological and anatomical changes. Refinement of the software, whereby this restlessness such as shorter lying periods will be detected as well could be useful for further research. In addition, in order to predict calving time, more parameters need to be combined to search for an algorithm which could be implemented in the daily use of dairy farmers.

CONCLUSIONS

It is clear that significant changes of length of lying bouts and total daily lying time indicate the imminent parturition. Refinement of measuring lying bouts, whereby lying periods shorter than fifteen minutes will be recognized as lying bout, is needed to find significant changes in number of lying bouts to imminent parturition. Further research to find significant changes in two-hour data is needed. For predicting the moment of birth with lying time, the change of circadian rhythm the last day prior to calving needs further research. Electronic data loggers could be useful as predictors of calving time, whereby lying behavioral variables may facilitate the implementation of a precision calving management program. The use of changes in lying behavior as indicators of imminent calving deserves further research, both for daily data as two-hour data.

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