# Can increased activity recorded with help of activity monitoring sensor indicate an upcoming calving?

## Kan ökad aktivitet registrerad med hjälp av aktivitetsmätare indikera en kommande kalvning?

**by**

**Hanna Persson**

**Institutionen för husdjurens utfodring och vård**
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**Examensarbete 367**
**30 hp A1E-nivå**

***Department of Animal Nutrition and Management***
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**Handledare/ *Supervisor*:** Madeleine Magnusson, Lantbrukets byggnadsteknik
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## FÖRORD

Detta examensarbete har genomförts av Hanna Persson inom agronomprogrammet HT 2010. Handledare har varit Madeleine Magnusson, Lantbrukets byggnadsteknik, SLU och Jan Bertilsson, Institutionen för husdjurens utfodring och vård, SLU har varit examinator.

Riktar ett stort och speciellt tack till Jan-Ove Johansson med familj på Dunsåsens gård utanför Nossebro för all hjälp och villighet att låta mig göra mina underökningar där. Ett stort tack även till Madeleine Magnusson som hjälpt mig i under projektets gång. Tackar även alla vänner och min familj som kommit med förslag, uppmuntrande ord och stöd under mitt genomförande av detta projekt! Tack!

Hanna Persson

2011-06-14

## FOREWORD

This thesis has been made of Hanna Persson within degree of Master of Science in agriculture HT 2010. Madeleine Magnusson, Rural building and animal husbandry, SLU, has been the supervisor and Jan Bertilsson, Department of animal nutrition and management, SLU, the examiner.

Sincere and a special thanks to Jan-Ove Johansson and his family at Dunsåsens farm outside Nossebro for all the help and willingness to let me do my research there. A great thank also to Madeleine Magnusson and Anders Herlin who helped me during this project. Also thanks to all my friends and family who had come with suggestion, encouragement and support during implementation of this project. Thanks!

Hanna Persson

2011-06-14

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# SAMMANFATTNING

Syftet med denna studie var att finna om rörelseaktiviteten i form av antal steg och liggtid med hjälp av en aktivitetsmätare kan upptäcka en påbörjad kalvning och därmed använda det som en indikator på en kommande kalvning. Till detta användes en aktivitetsmätare som monterades på kons ena bakben. Denna aktivitetsmätare mätte kornas individuella steg och rörelse-aktivitet samt frekvensen av stå och liggtid i %.

I studien användes 12 kor av rasen Simmental som alla kalvade mellan 5/11 till 10/12 – 2010. Korna inhystes under försöket i en ladugård med lösdrift med skrapgångar samt kalvgömma där kor och kalvar kunde röra sig fritt. Korna utfodrades en gång dagligen med fri tillgång på enbart ensilage.

I studien sågs det att antal steg ökade ifrån 7 dagar innan kalvning. Ett dygn innan kalvning sågs stegaktiviteten ytterligare öka fram till dess att kalvning skedde vilket var oberoende på vilket laktationsnummer kon befann sig i. Dock sågs skillnad i frekvens mellan ligg- och ståtid per dag beroende på vilket laktationsnummer kon hade. Äldre kor med 3-7 laktationer och enbart en kalv vid födsel sågs ha mer ligg- än ståtid, medel 57,4% och 42,6% per dag jämfört med kvigor, med enbart en kalv vid födsel, som hade en omvänd medel ligg- och ståtid 44,8% respektive 55,2% per dag. Utifrån studiens resultat ses att individens egna antal steg per dag är den mest säkra parametern att gå efter då det gäller att fastställa en tidpunkt för en kalvning.

## SUMMARY

The purpose of this study was to find out if motion movements, e.g. number of lying bouts and lying time with a registered activity monitoring sensor can detect an impending calving and thereby be used as a measure and an indicator for an upcoming calving. For this, automatically step sensors were used and were attached to one of the cows' hind leg. The sensor registered the individual step and movement activity of the cow. The frequency of standing and lying time were registered in percent.

The study used 12 cows of the Simmental breed, all calved between November 5 to December 10, 2010. The cows were under the study housed in a cowshed with loose housing system, alley scrapers and calf hide where cows and calves could move freely. The cows were fed once a day and had *ad lib* access to silage.

In the study it was seen that the number of steps increased from 7 days before calving. One day before parturition the step activity further increased until parturition occurred. The results were independent of what lactation number the cows had. However, there was a significant difference in frequency between lying and standing time per day depending on parity. Older cows with 3-7 lactations with only one calf at parturition seemed to have more lying time, mean 57.4% per day compared with heifers, with only one calf at parturition, mean 44.8% lying time. Based on the results from the study the cow's individual number of steps per day is the most reliable parameter to use when it comes to detect an impending calving.

# INTRODUCTION

During the previous year, 2009, the number of cattle were according to The Swedish board of Agriculture (Jordbruksverket, 2009) about 1.9 million in Sweden. The number of herds with a focus entirely on beef cattle was in 2007 approximately 10 500 (Granström & Jonasson, 2007). Buildings with loose housing system and cubicles for cattle are becoming more common (Olsson-Hägg, 2006). In cubicle system with scraping paths the scrapers should go 6-12 times a day to keep clean animals and reduce the risk of freezing of faeces and manure system during the winter. Within suckler cow production it is not recommended that the scraper runs automatically during the day, as there is risk that newborn calves can be injured or at worst follow the scrapers out to the culvert (Taurus & Svenska Djurhälsovården, 2008). It is therefore of great interest to estimate the time of calving for beef cattle, partly to avoid accidents in form of death at calving and also the financial loss that a dead calf contributes to. Within suckler cow production the calf is the part that brings in most of the income (Jordbruksverket, 2007).

The time before and after calving is called the transition period. It is a term that is defined with a time period of 3 weeks before calving to 3 weeks after calving. This time is the most important and significant to health, further lactation cycle and the profitability of the cow (von Keyserlingk & Huzzey, 2009; Huzzey *et al*. 2005; Drackley, 1999; Grummer, 1995). Different signs and most commonly used signs to predict the timing of calving is typically swelling and filling of the udder and relaxation of the pelvic ligaments. A normal calving occurs with head first (cranial presentation) but 5-10% of calves are born backwards (caudal presentation). Calving can be divided into three phases: opening, expulsion and the placental stage. The first two phases, which operates the calf from the mother, takes between 2.5 to 8.5 hours while the last phase expels the fetal membranes which usually occurres within 12 hours after delivery (Granström & Jonasson, 2007). It is therefore of great importance to know the steps and the various signs of a normal calving, in order to rapidly detect signs that if an initiated calving is abnormal (Berglund *et al.* 1987). Behaviour around calving and the date of calving in cows is a subject that for long time has been studied in various ways. Many studies demonstrate a correlation of calving time with reduced feed and water intake (Maltz & Antler, 2008; Huzzey *et al.*, 2005; Grant & Albright, 1995), while other studies show an increased number of steps with a reduction in lying time 24 hours before calving (George *et al.*, 2008; Maltz & Antler, 2008; Maltz & Antler, 2007).

The aim of this study was to find out if motion movements, e.g. number of lying bout and lying time registered with an activity monitoring sensor can detect an impending calving and thereby use that as an indicator for an upcoming calving.

# LITERATURE STUDY

## Natural behavior of cows and behavior at an impending calving

Cows are herd animals which handle their ranking through hierarchy, i.e. the hierarchy is sorted out without any open aggression that needs to be displayed. Age and size are the most significant, but also gestation - and health status are important parameters of where the cow ends up in the ranking. At an impending calving in the wild or on pasture the cow searches away from the herd, a day until a few hours before calving. The cow then searches after a suitable location for calving, which can proceed just until parturition (Jensen, 2006)

## Signs and external signals of impending calving

According to Granström & Jonasson (2007) evidences of an impending close calving are from a few days to a few weeks before i.e. that the udder fills with milk, pelvic ligaments become relaxed and the vulva begins to swell. Signs within a few hours before calving occurs can be poor appetite, restlessness, withdrawal from the flock, cow lifting her tail and urinates frequently, giving mucus and that the body temperature drops slightly.

Some of these signs are supported by a study of Berglund *et al.* introduced in 1987. In this research the process before calving and preparatory changes that occurred were studied. The research included 159 animals during their first and subsequent calving, total 493 calvings were studied. The animals were of the common Swedish breeds Swedish Friesian (SLB) and Swedish Red and White cattle (SRB). Cows that calved for the second time were crossed with one of the following breeds SRB, SLB or Swedish Jersey (SJB). Cows which gave birth to twins showed signs of preparing earlier than cows with one calf; however, no difference in preparing was seen between heifers and cows in their 2$^{nd}$ lactations. There were found a wide variation between individuals of the differences in external signs before parturition. External signs of relaxing of the pelvic ligaments, expansion and swelling of the vulva were the seen signs that were significantly increased of an initiation of parturition. Milk leaking from the udder and relaxed pelvic ligaments were the most reliable signs of that a calving should take place within 12 hours, but swelling and enlargement of the vulva were also reliable signs of an impending parturition.

## Body temperature changes associated with calving

Body temperature can be used as an indicator of cow health and reproductive status (Coppola *et al.*, 2002). A decreased body temperature is an effect of the cow's low metabolic rate (Gazzola *et al.*, 1995). Coppola *et al.* (2002) studied the cows' changes in body temperature some days before calving. The experiment used 50 cows, where both heifers and cows were mixed. There were 29 Brown Swiss cows and 21 of Holstein breed. The studies started 14 days before the calving were expected. In order to study the body temperature changes in the eye, side of the body and teats, an infrared thermal imaging camera and an infrared temperature gun were used. The closer the cows were to calving, there was a gradual decrease in body temperature per day the days before calving. Two days before calving, there was a marked difference in body temperature in the teat and body side. The temperature dropped more rapidly with a range from 0.3 to 1.1$^{o}$C during the last two days before parturition.

Temperature changes have likewise been seen in studies done by Lammoglia *et al.* (1997). In this study 7 cows were used, in which body temperature from 144 hours (six days) prior to calving and 24 hours (1 day) after calving was measured for 10 seconds every 3 minutes. Body temperature was seen to be lowest at night, 03.00 a.m. and highest, at 07.00 p.m. in the evening. Body temperature was relatively constant between 144-56 hours before calving and from 8-24 hours after calving. Between 48-8 hours before calving, there was a decrease in body temperature. Cows that gave birth to a heifer calve had a lower body temperature compared to a cow that gave birth to a bull calf. The body temperature therefore was considered to be affected by three factors: environmental temperature (time of day), hour before calving and sex of the calf.

## Eating and drinking behavior in relation to calving

Feeding behavior, feed intake, health and future production has a dramatic effect on pregnant cows and cows that are in the transition period i.e. 3 weeks before calving to 3 weeks after calving (Drackley, 1999; Grant & Albright, 1995; Grummer, 1995). Many studies have been made of how day or night feeding affect the calving time and the results have varied.

Huzzey *et al.* (2005) made a research where the aim was to study and determine how the feeding behavior changes during the period around calving. 15 cows in the transition period were used for the experiment. Measurements from 10 days before calving to 10 days after calving were performed. Based on these results, it was deduced that the number of feeding bouts increased after calving, versus before calving. However, it was seen that the total feeding time was lower decreasing from 87 min/day before calving to 62 min/day after calving. Similar results were seen by Drackley (1999) where the feeding time decreased gradually from 3 weeks before calving. Bertics *et al.* (1992) could in their studies show a

reduction in DM (dry matter) intake by 28% during the last week before calving. Bertics *et al.* (1999) results are supported by Journet & Remond, (1976); Lodge *et al*. (1975) and Coppock *et al*. (1972) who found similar results. After parturition the cows' metabolism increases with greater demands through increased milk production. Osborne *et al.* (2002) saw in their study that feeding time gradually increased in the weeks after calving. From week one to week three after calving DM intake was observed and increased by 40%. Bertics *et al.* (1992); Kertz *et al.* (1991); Nocek *et al.* (1983) and also found that DM intake rise the first weeks after calving.

Researchers have over the years studied if different feeding times during the day and night can affect the time of calving for the cow. These studies can facilitate and simplify the monitoring work at calving. Pennington & Albright (1985) showed that the feeding time did not significantly affect the calving time. Other research show an increase of day time calving cows compared to night calving cows when they were feed during night-time (Gleeson *et al*., 2003; Jaeger *et al*., 2002). Jaeger *et al.* (2008) used the results from two different herds with spring calving cows. One group was fed between 06.00 and 08.00 in the morning and one group between 16.00 and 18.00. The results were that morning fed cows calved more randomly throughout 24 hours during the day. Cows that were fed in the afternoon resulted in more calving during daylight hours. Similar studies and results previously have been disclosed by Pennington & Albright (1985) and Jaeger *et al.* (2002). A study was also made by Gleeson *et al.* (2003) where two different feeding times were tested on spring calving cows. Cows in group 1 had access to feed between 20.30 in the evening to 10.30 in the morning the day after. The second group had access to feed 24 hours a day, i.e. ad lib. feeding. Night calving counted hours between 00.30 and 06.29. The cows with access to feed only at night time had 9% less calving during night time compared to cows with ad lib. feeding. Cows with an ad lib. feeding were observed to have a more even distribution of calving during the day.

Dado & Allen (1993) claim and demonstrate in their study that drinking behavior was correlated with DM intake and the number of feed intake per day. Huzzey *et al.* (2005) studied the drinking behavior during the transition period. Data from cows from 10 days before calving to 10 days after calving were analyzed. The time cows spent drinking the days before calving was about 5.5 min/day depending on the individual and decreased a little bit the closer to calving the cows came. After calving the water intake increased steadily to 6.8 min/day at a rate of 0.4 min/day.

## Standing behavior in relation to calving

Huzzey *et al.* (2005) found that the standing time during the transition period was relatively constant, with a standing time of about 12.3 hours/day before calving and 13.4 hours/day after calving. However, a significant difference could be seen during the calving period, i.e. one day before calving to one day after calving. During this period the cows stood approximately

14.4 hours/day with an increase of two hours the day before calving and a one-hour increase after calving. This may demonstrate an increased activity around the calving period.

The number of standing bouts was not different before and after calving, however, there was a significant difference, similar to standing time, during the calving period, one day before and one day after calving. The number of standing bouts during the calving period increased by 80% during these two days around calving compared with the days before and after calving period. It is likely that this changes due to restlessness and a certain discomfort before calving (Huzzey *et al*., 2005).

## Lying behavior and step activity in relation to calving

According to many authors a cow's welfare and comfort can be estimated by studying their behavior. Haley *et al.* (2000) claimed that cows' behavior indicates how the cow comfort is in the barn. The duration and number of attempts to lie down, and the time they spend to get up without eating is some probable behavioral changes that can be used. Cows' total lying time per day last between 8-14 hours, which are spread across 15-25 periods. The duration of each lying bout vary from several minutes up to more than three hours, depending on whether the cow is disturbed or not. Factors such as age and other individual factors may also have an effect (Krohn & Munksgaard, 1993). Maltz & Antler (2007) made a study of activity and resting behavior in 12 cows before calving and 15 cows after calving. The behavior 24 hours before calving was different from before. The differences they saw were a greater step activity, greater restlessness and a decreased time to lie down. The day when calving occurred, the number of steps and resting time decreased and the ratio between the number of steps and lying time decreased in comparison with the rate the day before. Similar to Maltz & Antler (2007), George *et al.* (2008) did a study in which 15 heifers and 11 Holstein cows were included. From October to November in 2006 lying behavior, activity and heart rate 7-10 days before calving were studied as different parameters that could predict the calving time. Similar to Maltz & Antler (2007) it was observed that the total lying time and duration of the lying bouts during 24 hours before calving decreased, compared with other days. The total lying time the day when calving occurred was 9 hours. This proved to be significantly lower from earlier days before calving when the lying time was 12 hours. However, differences between cows and heifers were observed in lying time, the heifers lay down on average two hours less than cows. The duration of lying bouts was significantly lower for both heifers and cows one day before calving. Cows were considered to have more lying bouts than heifers. The day when calving occurred were lying bouts more in number compared with the previous day. Although the number of lying bouts was more, the duration of lying bouts significantly decreased the day when calving occurred. Lying bouts of less than 10 minutes was more often measured in contrast to the previous days. Another aspect that received attention during this study was that between 5 and 4 day before calving the duration of lying bouts decreased. This change is considered as a behavior change dependent to hormonal changes before calving.

Maltz & Antler (2006) presented a research where changes in step activity and resting behavior before calving were studied in 15 cows. Similar results as mentioned above were found, as the number of lying bouts increased from seven days before calving to the date when calving occurred. The total lying time and also the lying time per lying bout decreased. One could also see a greater restlessness of the cows by an increased activity in the seven days before calving. Numbers of steps increased from 2408 steps 7 days before calving to 8658 steps at the day when calving occurred. At 3 days before calving the number of steps decreased for a day and then increased again (figure 1).

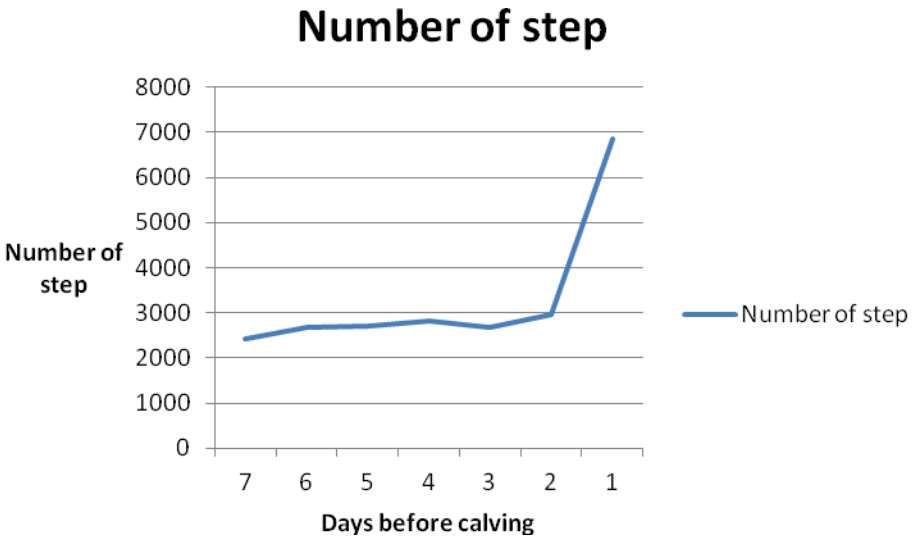



*Figure 1. Number of steps per day before calving (Maltz, 2006).*

## Hormone production during late pregnancy and at parturition

Many hormones are in circulation during pregnancy. All mammals need progesterone to maintain pregnancy. Progesterone and estradiol, which are a type of estrogen, interacts with each other during the pregnancy in a cow. Estradiol is low during pregnancy and increases dramatically at parturition. The progesterone concentration in plasma increases during pregnancy. Prior to birth the concentration of progesteron reduces (Sjaastad *et al*., 2003).

Lammoglia *et al.* (1997) showed in their study that the plasma concentration of progesterone ($P_4$), estradiol-17β ($E_2$) changed over time when parturition approached, $P_4$ decreased and $E_2$ increased. The concentration of thyroxine ($T_4$) which controls the metabolic rate and triiodothyronine ($T_3$) which controls the heat production and growth did not change as the parturition approached; however, they were affected by time of day. Lowest concentration appeared in the night, at 03.00 a.m. and highest concentration during the day, at 11.00 a.m. and 07.00 p.m. Similarly results have been put forward earlier by Arije *et al.* (1974). In their

study, levels of luteinizing hormone (LH), prolactine, estrogens, progestins and corticosteroids were measured in beef cows from one month prepartum to the second postpartum estrus. LH which controls the secretion of sex hormones had a lower concentration between 0.4-1.4 ng/ml 3 week before until the day of parturition. After parturition was the concentration of LH increased to between 0.5–2.0 ng/ml. Progestin which has nearly the same effect as progesterone (to maintain pregnancy) varied between 10–5.2 ng/ml from 21 to 14 days before parturition. At 3 days before calving a rapid decrease started and the day when parturition occurred the level of progesterone were fairly constant at 6 ng/ml and declined to 1.6 ng/ml the day after parturition. Estrogens which functions is to control growth and function of reproductive organs had a concentration between 572–1 300 pg/ml from 21–14 days before parturition. During the last two weeks before parturition the concentration levels increased to previous levels and then dropped to 592 pg/ml on the day when parturition occurred. The levels of prolactin which controls the production of milk were during late pregnancy below 50 ng/ml. From 4 days prior to parturition the concentration levels increased from 20 ng/ml to 348 ng/ml one day before parturition. At the day when calving occurred the concentration decreased to 250 ng/ml.

# FIELD STUDY

## Materials and methods

### *Farm and herd information*

The project was carried out on a farm outside Nossebro in Västra Götaland. The farm was runned by Jan-Ove Johansson and his family. The farm had autumn calving cows of Simmental breed in a new loose housing system with cubicles. The total number of animals was in the current situation around 60 cows but was going to be expanded to 80-90 cows. All cows were bred with a free range bull. During the experimental period the cows were held indoors in a loose housing system with cubicles and they had also access to deep straw bedding. Some parts of the straw bedding also acts as a calf hide to the calves. The animals were daily supervised, fed once a day in the morning, and had free access to water in the form of water bars. The cubicles were bedded with sawdust and the bed with straw.

### *Sensors*

The sensors that have been used in the study are of the model 3D Ice Tag (IceRobotics Ltd, Edinburgh, Scotland UK) which measure the cows activity in the form of steps, lying-, and standing movements, which means that movements forward, upward and sideways are recorded. This information is stored in a memory in the sensor, which later, when calving is over, is transferred to the computer and placed in an excel-file. Before the sensors were attached to the cows, they were activated with the help of a computer program. The sensors were then attached to one of the cow´s hind leg. To perform this operation safely and easily a treatment box was used and the cows could be locked in to minimize the risk of for example kicks and crushing injuries.

### *Implantation of study*

The study began on the 23$^{th}$ of October 2010. Twelve cows were then equipped with a separated activated sensor on one of the hind leg. The sensors were fastened with corresponding Velcro and then duct tape on the outside of the Velcro to minimize the risk that the sensors fall of when the cows rub against the edge of the cubicles. The cows were driven through an alley, and finally into a treatment box where the sensors were attached to the cow. The sensors should be attached to the cow at least 10 days before expected calving and then be taken off. Subsequently, the stored data in the sensor were transferred to the computer as cows calved. Due to few sensors the numbers of desired results were not enough; therefore

the sensors were removed, reactivated and put on new non-calved cows. This took place on 20th November when 8 cows had calved. In total, data from 22 cows were collected data from 12 of these cows have been included in the study. Other results were too uncertain due to illness, to premature parturition or not pregnant. The sensors should be attached at minimum 10 days before estimated parturition. Some cows had a prematurely parturition and other have been deleted due to e.g. illness and didn't received a relevant result.

The animal owner's role in this project was to note the date and approximate time of calving and other treatments, operations or disturbance implemented that happened during the time when the sensors were attached to the cows.

## *Statistics*

For statistical evaluation Minitab version 15.1 were used. To look at differences in cows' lying time, step and lying bouts a t-test between two samples (days) were used. T-test examines if the difference between the individual average values are random or if there is sufficient security to say that there is a difference known as significance level. Differences among means with a P-value < 0.05 were regarded as statistically different. A normal value for the cows is a value of day 10 (10 days before parturition) that represents the normal value of the individual cow´s behavior.

## Results

Of the total 22 cows in the study, could only data from 12 cows be included. Other results were too uncertain due to illness, to premature parturition or not pregnant. The animals which were included in the study are summarized in table 1.

*Table 1.Calvingdate, breed, age and any comment on calving for the animals included in the study between 23/10 - 10/12 – 2010.*

| **Cow number** | **Calving date and time of day** | **Breed** | **Lactation number** | **Comment** |
|---|---|---|---|---|
| **75** | December 10 at 11 am | Simmental | 7 | Twins, heifer calfs |
| **122** | November 18 at 3 pm | Simmental | 4 | Calved in the alley. Weak heifer calf, died after a few days. |
| **124** | November 5 at 4 pm | Simmental | 4 | Hiefer calf |
| **128** | November 14 at 12 pm | Simmental | 2 | Have been tied up cubicles to learn* between 9-14 November. Bull calf. |
| **151** | November 9 at 11 pm | Simmental | 3 | Bull calf |
| **154** | November 29 at 10 pm | Simmental | 3 | Twins, both came backwards. Easy to pull through. Heifer calfs |
| **157** | Decmber 10 at 12 am | Simmental | 3 | Have been tied up to cubicles between December 4-5 and 8-9 to learn*. Bull calf |
| **166** | November 26 at 13 pm | Simmental | 2 | Heifer calf |
| **171** | November 13 at 9 pm | Simmental | 2 | Heifer calf |
| **173** | November 23 at 10 pm | Simmental | 1 | Heifer calf |
| **174** | November 13 at 04 am | Simmental | 1 | Bull calf |
| **196** | December 9 at 10 am | Simmental | 2 | Heifer calf |

*The cows were tied up in the cubicles with a rope

A trend could be seen in the number of lying bouts, which increased from 1 to 2 day before parturition. Nine of 12 cows had their highest number of lying bouts the day when calving appeared, (table 2a and 2b). A statistical analyze showed a significant difference of lying bouts on the day when parturition appeared, compared to the normal value of lying bouts for the cows ($p < 0.05$). No other differences could be seen between other days before parturition. Table 2a shows multiparous cows plus the cows that gave birth to twins and table 2b shows primiparous and biparous cows.

*Table 2a. Average number of lying bouts per day, 10 days before parturition.*

| ***Cow number/day*** | ***75*** | ***154*** | ***124*** | ***157*** | ***122*** | ***151*** |
|---|---|---|---|---|---|---|
| **10** | 22 | 6 | 6 | 14 | 46 | 16 |
| **9** | 22 | 6 | 13 | 16 | 36 | 16 |
| **8** | 21 | 7 | 14 | 12 | 44 | 13 |
| **7** | 24 | 5 | 16 | 20* | 48 | 16 |
| **6** | 19 | 7 | 21 | 20* | 52 | 13 |
| **5** | 21 | 7 | 24 | 10 | 41 | 17 |
| **4** | 28 | 5 | 18 | 10 | 45 | 14 |
| **3** | 23 | 6 | 21 | 13* | 53 | 13 |
| **2** | 24 | 9 | 17 | 17* | 45 | 16 |
| **Parturition day** | 25 | 35[1] | 15 | 14 | 65[1] | 25[1] |

*[1)] Numbers shows the cows with highest number of lying bouts on parturition day.*
**tied up*

*Table 2b. Average number of lying bouts per day, 10 days before parturition.*

| **Cow number/day** | **128** | **166** | **171** | **173** | **174** | **196** |
|---|---|---|---|---|---|---|
| **10** | 17 | | 14 | | 20 | 7 |
| **9** | 18 | | 17 | | 15 | 6 |
| **8** | 18 | | 14 | | 20 | 3 |
| **7** | 19 | | 13 | | 18 | 10 |
| **6** | 18* | 14 | 17 | | 13 | 11 |
| **5** | 19* | 13 | 14 | | 18 | 9 |
| **4** | 33* | 15 | 17 | | 18 | 10 |
| **3** | 29* | 13 | 18 | 15 | 18 | 9 |
| **2** | 27* | 13 | 14 | 11 | 16 | 6 |
| **Parturition day** | 36[1]* | 20[1] | 22[1] | 41[1] | 53[1] | 16[1] |

*[1)] Numbers shows the cows with highest number of lying bouts on parturition day.*
**tied up*

The total lying time per cow depended on the individuals and their lactation number. Table 3a and 3b shows the total lying time per day for each cow.

*Table 3a. Total lying time (min) per cow and day, 10 days before parturition.*

| Cow number / day | 75 | 154 | 124 | 157 | 122 | 151 |
|---|---|---|---|---|---|---|
| **10** | 630 | 514 | 950 | 970 | 930 | 1035 |
| **9** | 587 | 344 | 1149 | 941 | 859 | 1020 |
| **8** | 612 | 567 | 1052 | 858 | 747 | 967 |
| **7** | 704 | 349 | 1069 | 1012* | 851 | 967 |
| **6** | 715 | 351 | 996 | 684* | 822 | 966 |
| **5** | 695 | 488 | 1008 | 738 | 826 | 967 |
| **4** | 696 | 354 | 954 | 721 | 836 | 967 |
| **3** | 698 | 351 | 917 | 840* | 829 | 950 |
| **2** | 698 | 442 | 777 | 889* | 843 | 974 |
| **Partirition day** | 665 | 889 | 832 | 564 | 714 | 1032 |

**tied up*

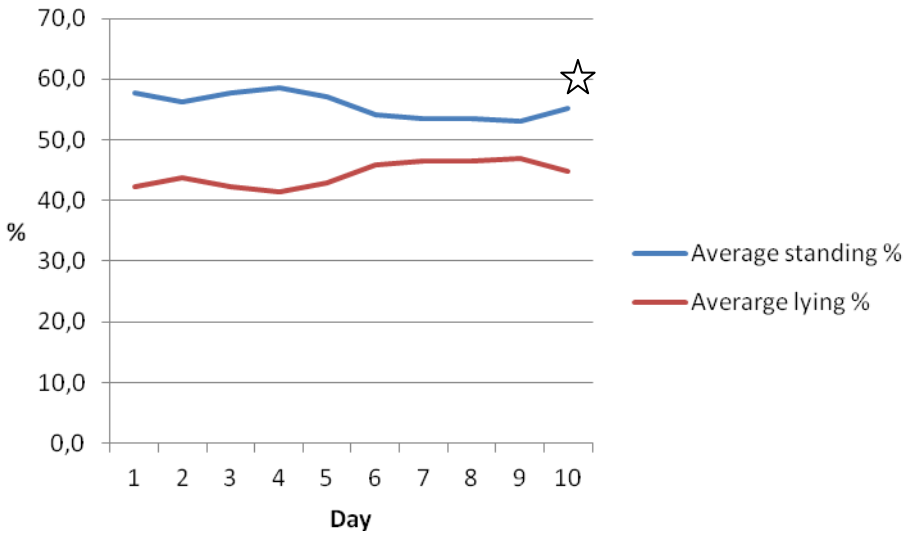
*Table 3b. Total lying time (min) per cow and day, 10 days before parturition.*

| Cow number / day | 128 | 166 | 171 | 173 | 174 | 196 |
|---|---|---|---|---|---|---|
| **10** | 574 | 0 | 646 | 0 | 609 | 482 |
| **9** | 558 | 0 | 636 | 0 | 629 | 519 |
| **8** | 573 | 0 | 659 | 0 | 607 | 516 |
| **7** | 578 | 0 | 655 | 0 | 597 | 462 |
| **6** | 617* | 630 | 691 | 0 | 619 | 430 |
| **5** | 617* | 653 | 691 | 0 | 660 | 391 |
| **4** | 636* | 686 | 696 | 0 | 669 | 334 |
| **3** | 691* | 669 | 727 | 819 | 669 | 335 |
| **2** | 593* | 630 | 712 | 848 | 675 | 368 |
| **Partirition day** | 590* | 649 | 660 | 843 | 643 | 396 |

**tied up*

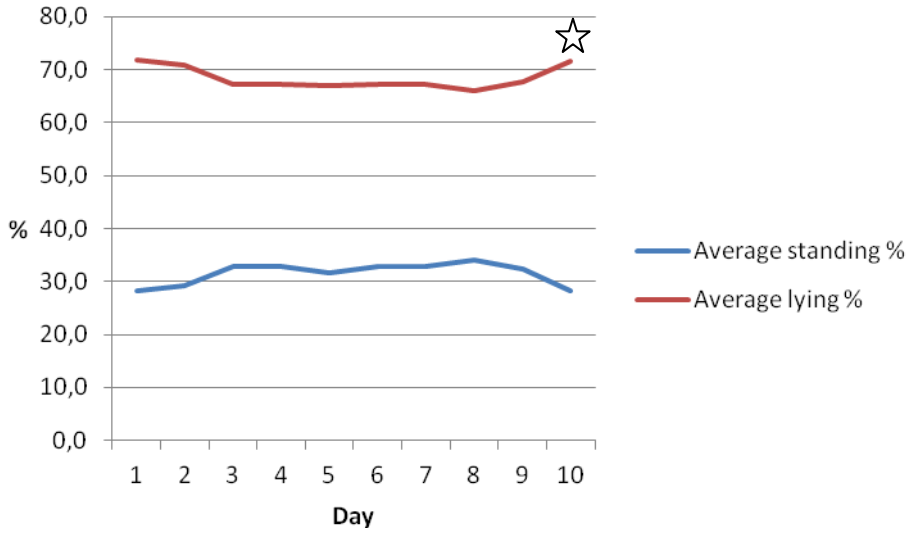
When the results regarding lying and standing time in percent per day before calving were evaluated, a difference could be seen, depending on which lactation number the cow had. Heifers and cows in their 2$^{nd}$ lactation had a more evenly distributed time of lying and standing behavior the days before parturition than cows with more, 3-5, lactations who had a more irregular frequency of lying and standing pattern of time per day, see figure 2 and 3. Cows that were in their 3$^{rd}$ to 5$^{th}$ lactation had an average between 32.9 - 68.5% lying time

and 31.5 - 64.1% standing time per day the last 10 days before parturition. Heifers had an average between 41.9 –70.6% standing time and between 29.4 – 58.1% lying time per day (table 4). Figure 2 and 3 show the difference between an example of a heifer and a cow in her 3rd lactation.




☆ Day of parturition

*Figure 2. Cow number 174, heifer. Difference between standing and lying time in % per day, 10 day before parturition.*




☆ Day of parturition

*Figure 3. Cow number 151, 3rd lactation. Difference between standing and lying time in % per day, 10 days before parturition.*

*Table 4. Lactation number, average standing, - and lying time in % for each individual 0-10 days before parturition.*

| cow number | lactation number | average standing % | average lying % | Twinbirth |
|---|---|---|---|---|
| **173** | 1 | 41.9 | 58.1 | |
| **174** | 1 | 55.7 | 44.3 | |
| **128** | 2 | 58.7 | 41.3 | X |
| **166** | 2 | 54.6 | 45.4 | |
| **171** | 2 | 53.0 | 47.0 | |
| **196** | 2 | 70.6 | 29.4 | |
| **151** | 3 | 31.5 | 68.5 | |
| **154** | 3 | 64.1 | 32.9 | X |
| **157** | 3 | 45.6 | 57.4 | |
| **122** | 4 | 42.6 | 57.4 | |
| **124** | 4 | 39.9 | 60.1 | |
| **75** | 7 | 53.4 | 46.6 | |

When comparing the lying time per day deviated with number of lying bouts a significant difference could be seen in the duration of each lying period (Table 5). At parturition day, more lying bouts were found compared to the normal frequents, day 10 before parturition, for the cows and resulted in more and shorter lying bouts. Day 9 to 2 before parturition had almost the same results as day 10 before parturition and no significant difference could be seen.

*Table 5. Difference between the number of lying bouts at day 10 before parturition (normal value) and at parturition day and the time per lying bout at the different days.*

| Cow number | Number of lying bout at day 10 before parturition | Time per lying bout (min) | Number of lying bout at parturition day | Time per lying bout (min) |
|---|---|---|---|---|
| **75** | 22 | 29 | 25 | 27 |
| **154** | 6 | 86 | 35 | 25 |
| **124** | 6 | 158 | 15 | 55 |
| **157** | 14 | 69 | 14 | 40 |
| **151** | 16 | 20 | 25 | 11 |
| **128** | 17 | 65 | 36 | 41 |
| **122** | 46 | 20 | 65 | 11 |
| **166** | | | 20 | 32 |
| **171** | 14 | 46 | 22 | 30 |
| **173** | | | 41 | 21 |
| **174** | 20 | 30 | 53 | 12 |
| **196** | 7 | 69 | 16 | 25 |

Eleven of 12 cows had an increased number of steps from day 7 to parturition day but no significance could be seen. Significant differences were found between 10 to 7 days before parturition compared to the number of step at parturition day ($p < 0.05$). A comparing between the normal numbers of steps averaged for each individual with the number of step that each individual had at parturition day shows that 8 of 12 cows had a higher number of steps at the parturition day. Further 2 of 12 cows, had their highest number of steps the day before parturition and one cow had her highest number of steps 3 days before parturition (table 6a and 6b). The only cow, number 75 (7 lactations), that did not follow these trends had a higher number of lactations, this cow had a more even pattern of around 50% per day of lying and standing time, respectively compared to the other cows in the study, see figure 4. Cows in their 1$^{st}$ or 2$^{nd}$ lactation stood more during the day and had also a higher number of steps compared to other multiparous cows.

*Table 6a. Average number of step per day, 10 days before parturition.*

| Cow number/day before parturition | 75 | 154 | 124 | 157 | 122 | 151 |
|---|---|---|---|---|---|---|
| **10** | 971[2] | 1185[2] | 1274[2] | 783[2] | 682[2] | 1565[2] |
| **9** | 742[2] | 1155[2] | 675[2] | 1192[2] | 976[2] | 1622[2] |
| **8** | 1027[2] | 1040[2] | 784[2] | 1125[2] | 740[2] | 1778[2] |
| **7** | **1296** | 1154 | 588 | 388* | **896** | 1783 |
| **6** | **2226** | 1119 | 956 | 917* | **917** | 1785 |
| **5** | **1620** | 1057 | 1132 | **1425** | **912** | 1783 |
| **4** | **1491** | **1289** | 1019 | **1405** | **967** | 1783 |
| **3** | **1259** | **1194** | 1105 | **538*** | **1396[1]** | **1885[1]** |
| **2** | **1227** | **1630[1]** | **1438[1]** | **310*** | **868** | **1795** |
| **Parturition day** | **1009** | **1077** | **1241** | **1879[1]** | **1220** | **1644** |

***Fat*** *numbers show the day when the number of steps starts to increase before parturition compared to day 10 before parturition.*

[1] *shows the day when the cow had their highest number of step before parturition.*

[2] *shows the days which have significant difference against parturition day*

**tied up in cubicle*

*Table 6b. Average number of step per day, 10 days before parturition.*

| Number | 128 | 166 | 171 | 173 | 174 | 196 |
|---|---|---|---|---|---|---|
| **10** | 719[2] | | 1952[2] | | 1838[2] | 1757[2] |
| **9** | 742[2] | | 1958[2] | | 1772[2] | 1683[2] |
| **8** | 752[2] | | 1901[2] | | 1809[2] | 1712[2] |
| **7** | **769** | | 1936 | | **1885** | **1948** |
| **6** | **741*** | 1963 | **2028** | | **1835** | **2233** |
| **5** | **720*** | 1931 | **2115** | | **1882** | **2558** |
| **4** | **747*** | 1856 | **2219** | | **2062** | **2853** |
| **3** | **798*** | 1966 | **2168** | 1328 | **2187** | **3291** |
| **2** | **898*** | 2074[1] | **2223** | 1311 | **2372** | **3434** |
| **Parturition day** | **939[1*]** | 2072 | **2319[1]** | 1395[1] | **2462[1]** | **3465[1]** |

***Fat*** *numbers show the day when the number of steps starts to increase before parturition compared to 10 days before parturition.*

[1] *shows the day when the cow had their highest number of step before parturition.*

[2] *shows the days which have significant difference against parturition day*

**tied up in cubicle*

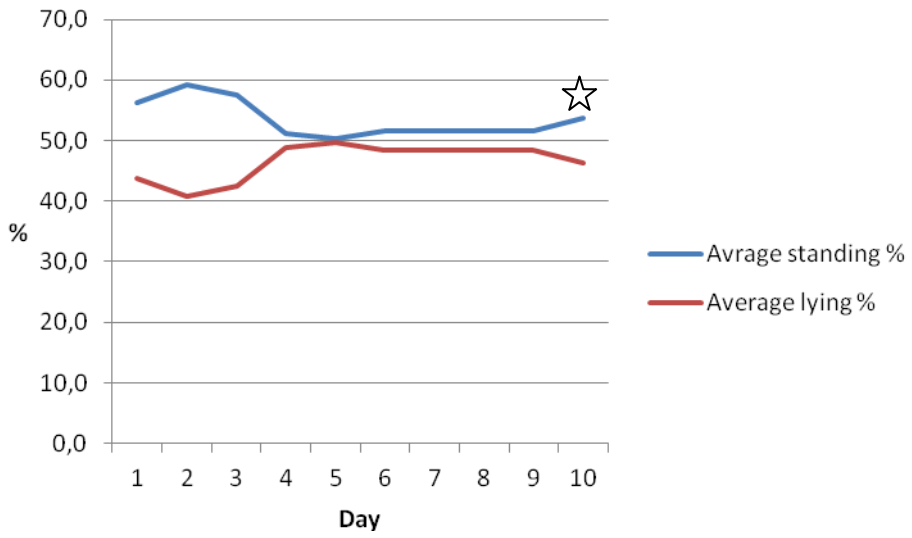



*Figure 4. Cow number 75, 7 lactations. The figure shows the lying and standing activity in percent. Shows a different lying and standing pattern compared to the other cows in the study.*

Maximum number of steps, depending on the individual, was between 3 days before calving and parturition day. Comparing one day's number of steps trough the total lying time over a day no great differences between the 10 different days before calving were found. A difference was found between younger and older cows. Younger cows with less lactations, 1-2, had a larger ratio between the two parameters, which indicate a larger step activity and less lying time closer to parturition the cow came. Older cows with more lactations had a smaller and more even ratio between the two parameters, which depended on less time per lying bout per day compared to cows with less lactations and a small amount of steps per day. Figure 5 and 6 shows the ratio between the number of steps and the total lying time per day. Cow 151 with three lactations had a smaller ratio compared with cow 196 with two lactations. Significant differences could be seen 10 to 7 days before parturition compared to the number of step/lying time at parturition day ($p < 0.05$). No other differences could be seen between other days before parturition.

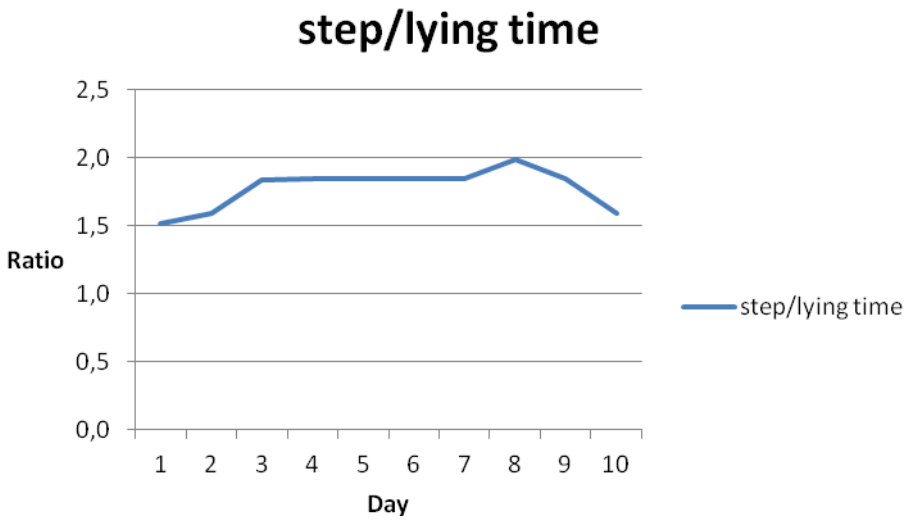



*Figure 5. Cow number 151, 3rd lactation. The ratio between step and lying time per day over 10 days before parturition.*

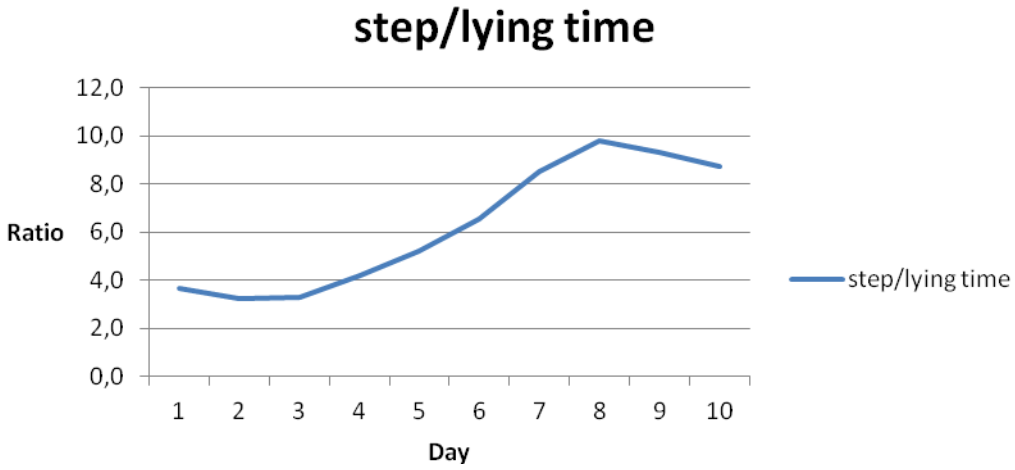



*Figure 6. Cow number 196, 2nd lactation. The ratio between step and lying time per day over 10 days before parturition.*

Cow number 75 began her 7th lactation and gave birth to twins. Her percentage of lying and standing time per day was equal to cows with one or two lactations at parturition see table 3. Figure 7 shows the cow number 75 average standing and lying time in percent over 10 days before parturition. The cow lay down on average 46.6% of the days and stood 53.4% of the day, during the 10 days before calving. For the second cow, number 154, which also gave birth to twins, was the proportion of lying and standing time different both from cow number 75 and the other non-twin calving multiparous cows. Cow 154, which began her third

lactation, had a bigger proportion of standing time (65.1%) than lying time (34.9%), see figure 8.

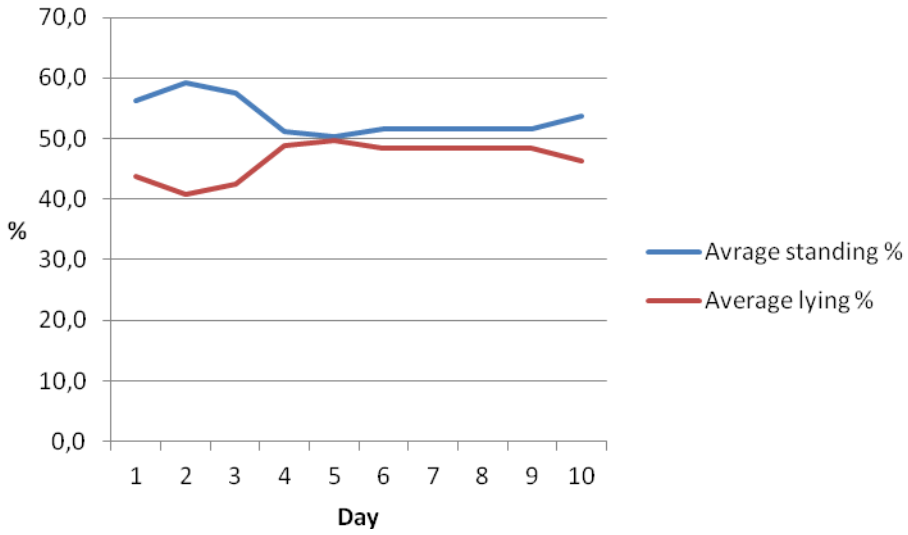



*Figure 7. Cow number 75, 7th lactation, twin birth. Average standing and lying time in percent over the 10 days before parturition.*

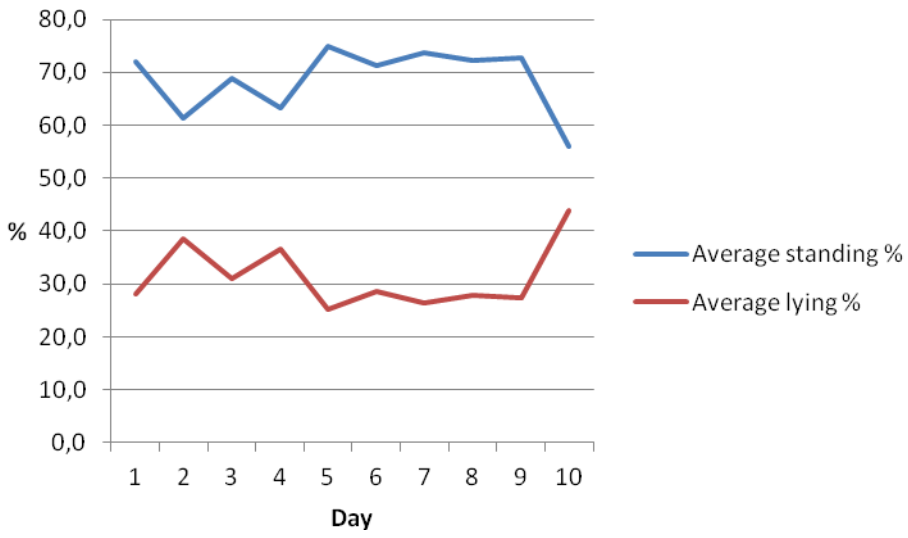



*Figure 8. Cow number 154, 3rd lactation, twin birth. Average standing and lying time in percent over the 10 days before parturition.*

To find out how many of the cows that could have been identified, at least 24 hours prior to calving, the following analysis was made. Day 10's normal step value (table 6 a & b) was

increased by 25, 20 and 10% for each cow. Then these values were compared to the step value of each day until 24 hours before parturition. This has been done in the 8 cows that had activity sensor on the entire 10-day period and not were tied up in the cubicles. In total 8 cows have been analyzed. Based on calculations (table 7) in this study 62.5% of the parturitions could have been indentified at day 2 when the normal value of step was increased by 25%. At 10%, 100% the cows could at day 2 have been indentified to begin their parturition within 24 hours. Day 7 was the day when a calving at the earliest in this study could be detected for all levels of percent, 25, 20 and 10%, respectively (table 7).

*Table 7. Shows when parturition could be detected were the normal value of step were increased by 25, 20 and 10%.*

| | 25% level | | | | | | |
|---|---|---|---|---|---|---|---|
| | Days before parturition | | | | | | |
| Cow no. | Parturition | 2 | 3 | 4 | 5 | 6 | 7 |
| 75 | | X | x | x | x | x | x |
| 154 | | X | | | | | |
| 124 | | | | | | | |
| 122 | x | X | x | x | x | x | X |
| 151 | | | | | | | |
| 171 | | | | | | | |
| 174 | x | X | | | | | |
| 196 | x | X | x | x | x | x | |
| Total | 37.5% | 62.5% | 37.5% | 37.5% | 37.5% | 37.5% | 25% |

| | 20% level | | | | | | |
|---|---|---|---|---|---|---|---|
| | Days before parturition | | | | | | |
| Cow no. | Parturition | 2 | 3 | 4 | 5 | 6 | 7 |
| 75 | | X | X | x | x | x | X |
| 154 | | X | | | | | |
| 124 | | | | | | | |
| 122 | x | X | X | x | x | x | X |
| 151 | | | X | | | | |
| 171 | | | | | | | |
| 174 | x | X | | | | | |
| 196 | x | X | X | x | x | x | X |
| Total | 37.5% | 62.5% | 50% | 37.5% | 37.5% | 37.5% | 37.5% |

| | 10% level | | | | | | |
|---|---|---|---|---|---|---|---|
| | Days before parturition | | | | | | |
| Cow no. | Parturition | 2 | 3 | 4 | 5 | 6 | 7 |
| 75 | | X | X | x | x | x | x |
| 154 | | X | | | | | |
| 124 | | X | | | | | |
| 122 | x | X | X | x | x | x | x |
| 151 | | X | X | x | x | x | x |
| 171 | x | X | X | x | | | |
| 174 | x | X | X | x | | | |
| 196 | x | X | X | x | x | x | x |
| Total | 50% | 100% | 75% | 75% | 50% | 50% | 50% |

# DISCUSSION

The activity of cows before calving changes which has been shown in several previous studies (Huzzey *et al*. 2005; Maltz & Antler, 2008). Step activity has previously been seen to increase from seven days before calving until parturition. Three days before parturition a decreased number of steps was seen, but then increased the number of steps again before parturition (Maltz, 2006). In the study made here, some similar results could be found and a significant increase in the number of step is observed from 7 days before parturition. From one day before parturition until parturition an increased activity and number of steps can be seen. This can have a possible relationship with the cows natural behavior, where they move away from the herd about 24 hours before parturition to find the optimal place to give birth at (through this the step activity increase).

When comparing the difference of a normal step averaged in each individual with the step value that each individual had at parturition day, the number of step is higher and a significant difference can be seen. However, an exception is cow number 128, this can possibly be explained by the reason that she was tied up in the cubicle the days before parturition and then was released before she started to calf.

For heifers it was seen that the numerical difference of lying time was less than for the cows. A heifer lay on average 53% per day while a cow in the $3^{rd}$ to $5^{th}$ lactation lay on average 60% per day. Interesting to see was that the cow in her $7^{th}$ lactation which also gave birth to twins had a decreased lying time per day compared to cows in $3^{rd}$ to $5^{th}$ lactations. A possible explanation to that can be that it was more uncomfortable for her to lie down compared to other cows in a later lactation. What´s different here is that lying time and standing time is more like a cow in the first or second lactation, with a small difference between lying- and standing time per day. In this study it was two cows that gave birth to twins, number 75 that are mention above and cow number 154. Cow number 154 differed from other cows with several lactations by having inverted lying and standing patterns. Cow number 154 stood on average 65.1% and lay on average 34.9% per day, during the last ten days before parturition. Other cows with the same lactation number stood on average 41% and lay on average 59% per day. A possible explanation can be that giving birth to twins results in a more uncomfortable lying period the last ten days before parturition and they may have too little energy to stand up; therefore the rate between standing and lying time becomes less. It would have been interesting to do a statistical study on whether this result is significant or not, but it is not possible in this study because of too few results.

Furthermore, the curves were observed to be more even for both step activity, lying time (%) and standing time (%) of heifers than for cows, during the 9 days before parturition. Cows lay on average more during the day then heifers. Thus the day when parturition occur a change can be seen and particularly the activity around 6 hours before parturition. During these hours the activity becomes more irregular for heifers than for cows. This may probably be due to heifers is more worried than older cows. A natural explanation can also be the hormonal status that drastically changes during the period before and around parturition. The results in

this study can be compared and supported by the study made of George *et al.* (2008). In that study, it was seen that all cows regardless of lactation number lay about three hours less during the last 24 hours before parturition. This was seen to be significantly lower from earlier days before calving, when the lying time for heifers were 12 hours. Differences between cows and heifers were also seen to be significant when the heifers on average lay two hours less per day. Common to both heifers and cows was that the duration of each lying bout was significantly less during the day when parturition occurred than during the previous days.

A comparison between one days number of step through the total lying time over a day a small (compared to value of significance between step) significant differences could be seen between the 10 to7 days before calving compared to parturition day. A difference can also be seen between primi- or biparous cows. These younger cows have a larger ratio between the two parameters than older cows. This indicates of a larger step activity and less activity to lay down the closer to parturition the cow will come. Multiparous cows seem to have a smaller and more even ratio between the two parameters which depends on that older cows have less time per lying bout per day compared to cows with less lactations and a small amount of steps per day. Similar results were found in studies done by Krohn & Munksgaard, (1993) and Maltz & Antler (2007).

Berglund *et al.* (1987) found in their study that cows in later lactations, which gave birth to twins, had a longer preparation time. In this study it can´t safely be said that twin birth gave a longer preparation time because of the small amount of calving occasion with twins, but the results indicate the same. As mentioned earlier two parturitions with twins occurred during the study. The cows were in their $7^{th}$ and $3^{rd}$ lactation, respectively. For the cow with 7 lactations it can be seen that the numbers of steps increased slightly 5-4 days before calving and then decreased until calving occurred. For the other cow in the $3^{rd}$ lactation, a drastic increase in steps two days before calving occurred and then dropped sharply 24 hours before the parturition. To do better comparisons of the behavior it would have been interesting to study twin births of a larger number of heifers and cows in an early lactation number.

The results of this study showed that the numbers of steps for each cow are the most strongly evidence to secure a date for calving. However, it is difficult to draw a general conclusion from the number of steps per day for all the cow because of the individual number of steps per day differs from individual to individual. A further development of this study would be to get a unique value for each cow, a value that represents the normal number of steps per day. In this study would at day 2, 62.5% be discovered at least 24 hours (day 2) before parturition if day 10´s normal value were increased by 25%. If day 10´s normal value were increased by 10% could 100% be discovered 24 hours (day 2) before parturition. The impact with a lower percentage is that more cows are detected before parturition but the certainty that they calves within 24 hours are less.

The time before and after calving is called the transition period, and is defined with a time period of 3 weeks before calving to 3 weeks after calving. These weeks are the most important and significant to health, further lactation cycle and the profitability of the cow. In

this study, the normal value was set to 10 days before calving. This could be misleading by not knowing anything about how the activity for the cow was before those 10 days. In further studies, it would be a wish to get a normal value (number of steps/day) based on an average of the step activity during days, a average of 14 days before these 10 days that was measured could be compared, partly to get a safe average that eliminating any differences of a day when something may have happened in the stable or on pasture that is not equivalent to a normal day for the cow. Furthermore, this gives us an individual limit for each cow and the secure to establish a calving date increases. How many parturitions that could be ensured with this method is impossible to say due to the small number of cows used in this study, but on the results and graphs that are obtained, a greater proportion of the cows show a pattern of increasing step when parturition are approaching. Also the number of lying bouts, with decreased duration of lying time per lying bout, at parturition day increased compared to earlier days.

# CONCLUSION

Activity and step activity before calving depends on the individuals natural activity, lactation number and if they will give birth to twins or not. To determine with 100% certainty the cow's calving time by their activity is still a bit uncertain due to too few observations in this study. However, it can with fairly high certainty be said in this study, that the activity started to increase from 7 days before calving. At 24 hours before parturition a further increased step activity was observed. Through an increased step frequency also the number of lying bouts increased while the duration of these decreased during the last 24 hours before calving. This indicates an increased activity and anxiety in the last 24 hours before calving. The aim of the study were to find out if motion movements, e.g. number of lying bout and lying time registered with an activity monitoring sensor could detect an impending calving and thereby use that as an indicator for an upcoming calving. The results show:

- The number of steps per day is a parameter that gives us the most certain answer to when parturition will occur. Significant differences could be seen 10 to 7 days before parturition compared to the number of step at parturition day.
- 8 of 10 cows had a higher step activity at parturition day compared to previous days before calving.
- Significantly larger number of lying bouts was found at parturition day compared to day 10 to day 2 before parturition.
- Significant differences of the number of step/lying time could be seen between parturition day and 10 to 7 days before parturition.

In this study a larger portion of the calving would have been anticipated with help of sensors that register the activity of the individual cows. However, the human eye is a must, and is above all a great advantage in the work in the period before and around calving.

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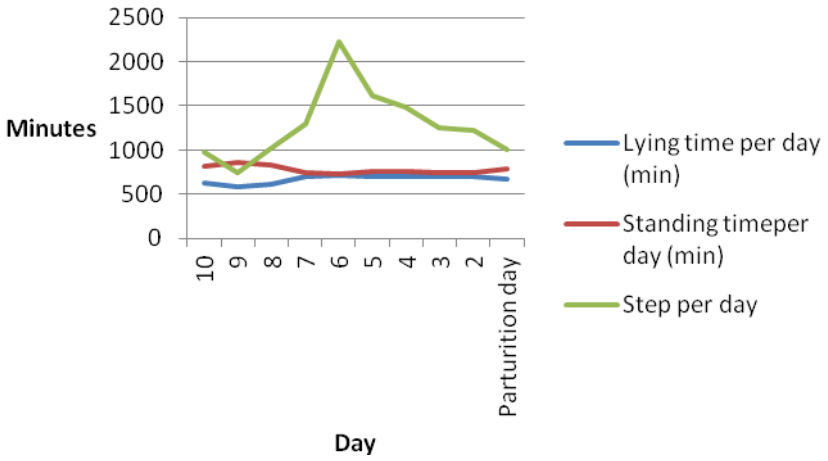
# APPENDIX

## Appendix 1 – Basic data

Cow 75

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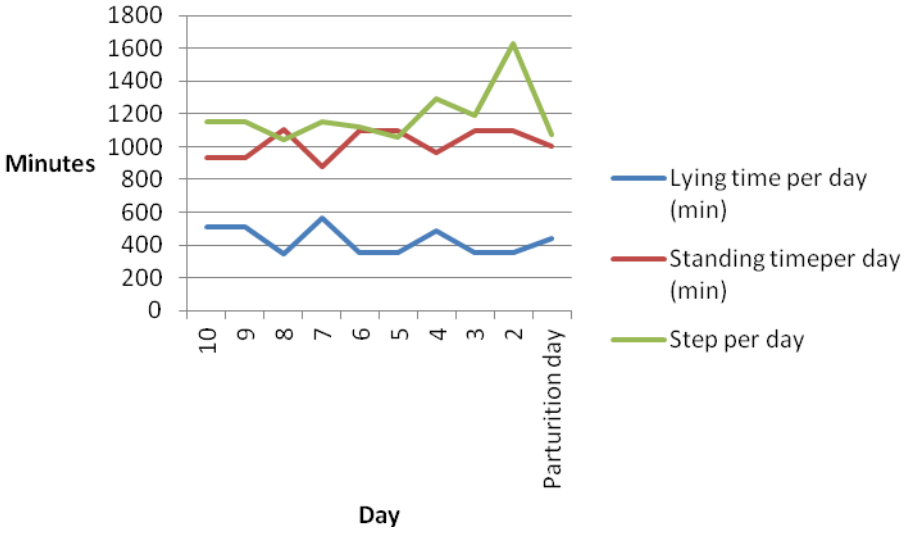

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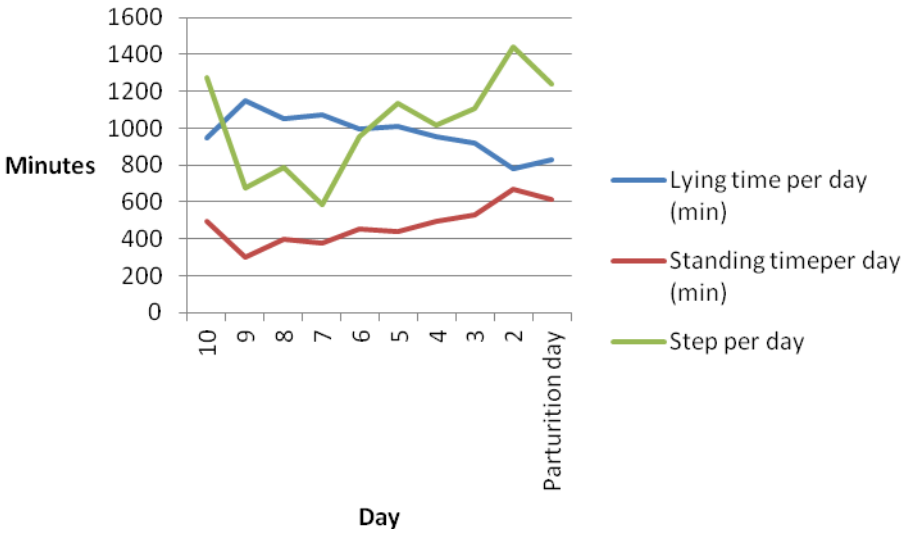


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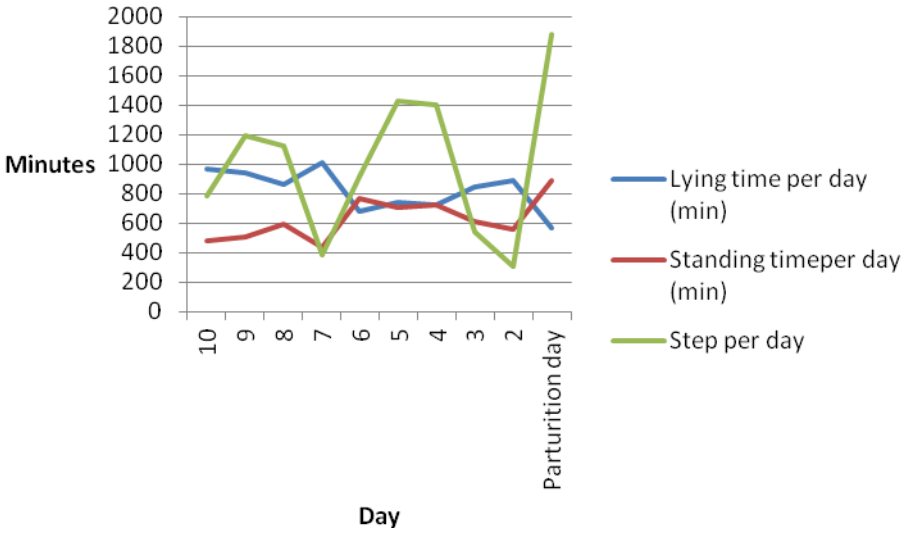

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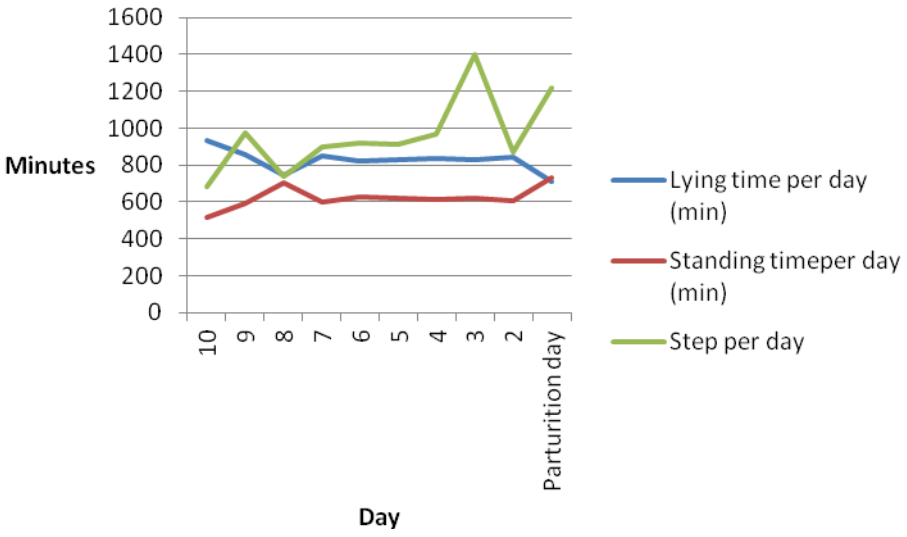


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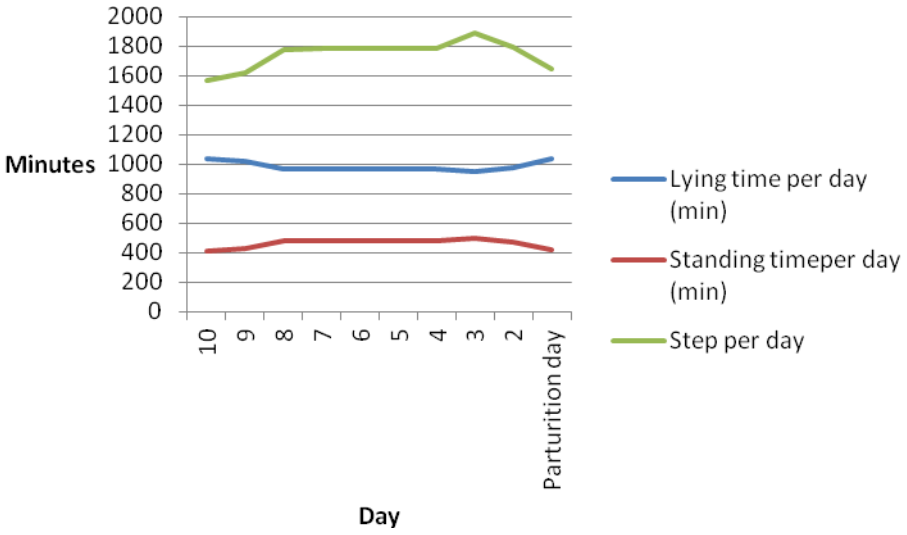

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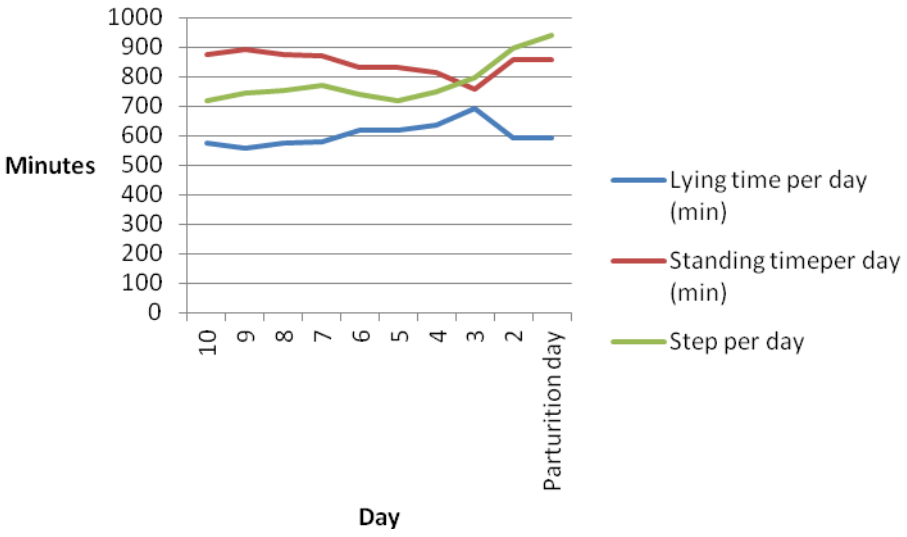


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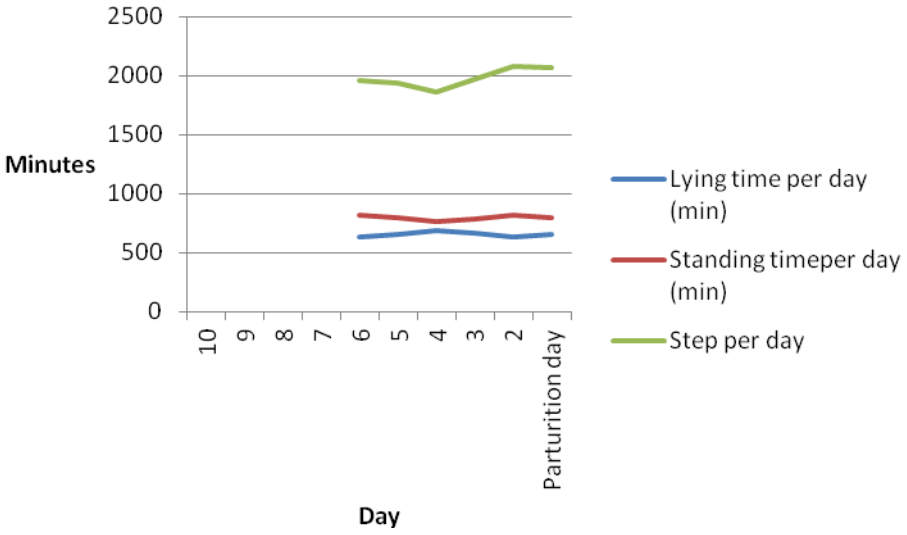

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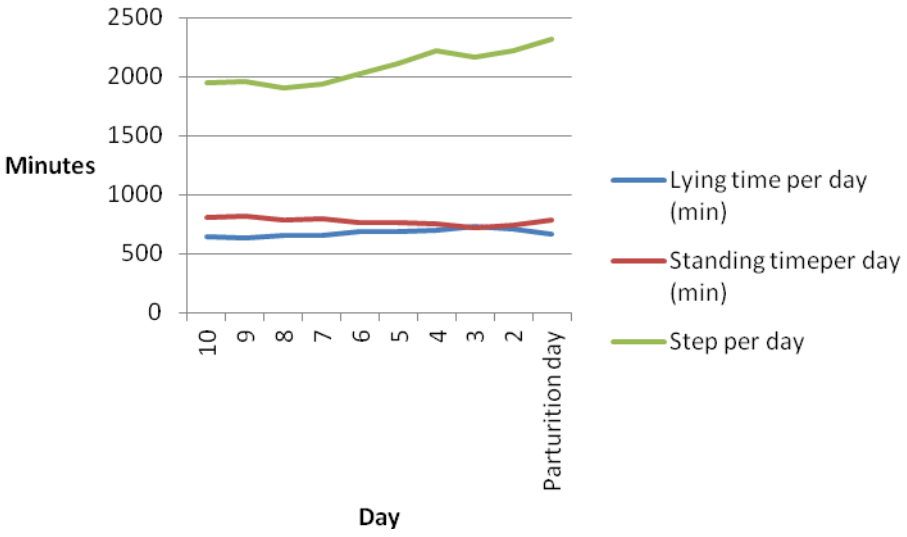


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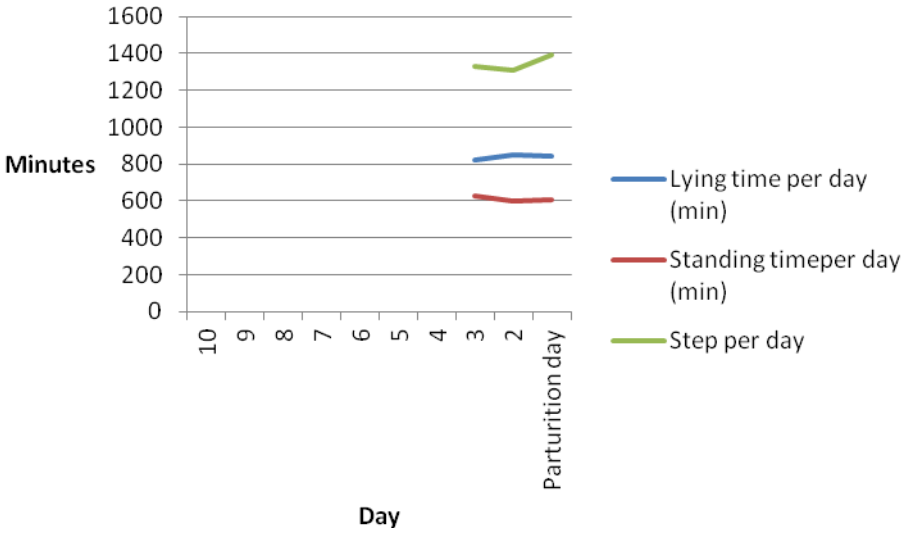

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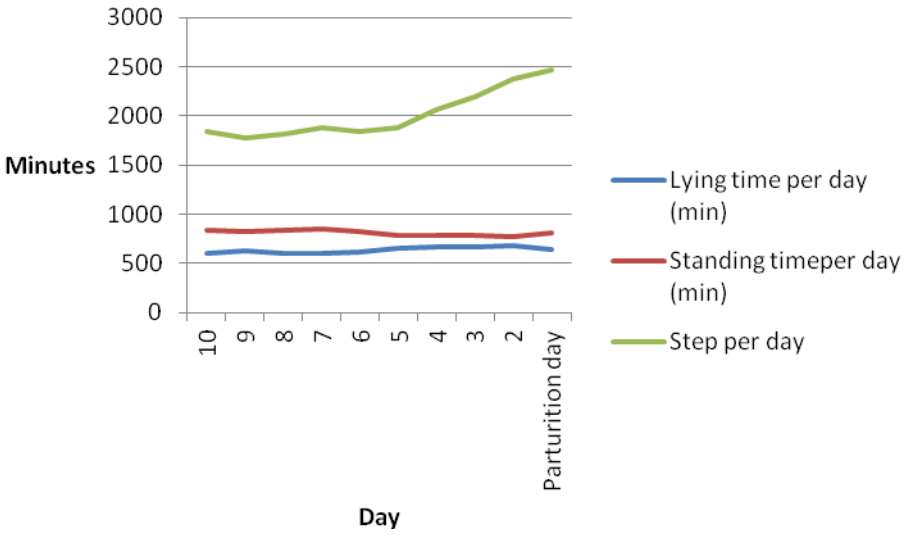


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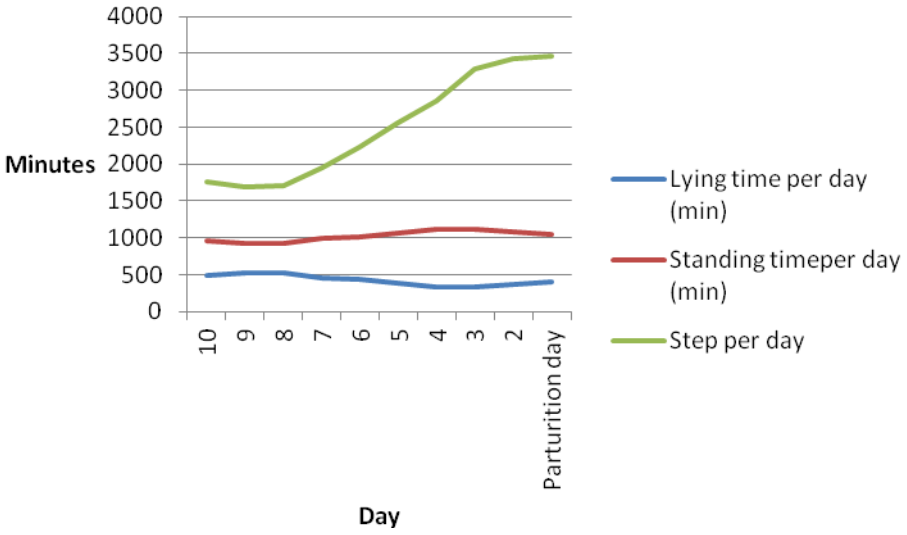
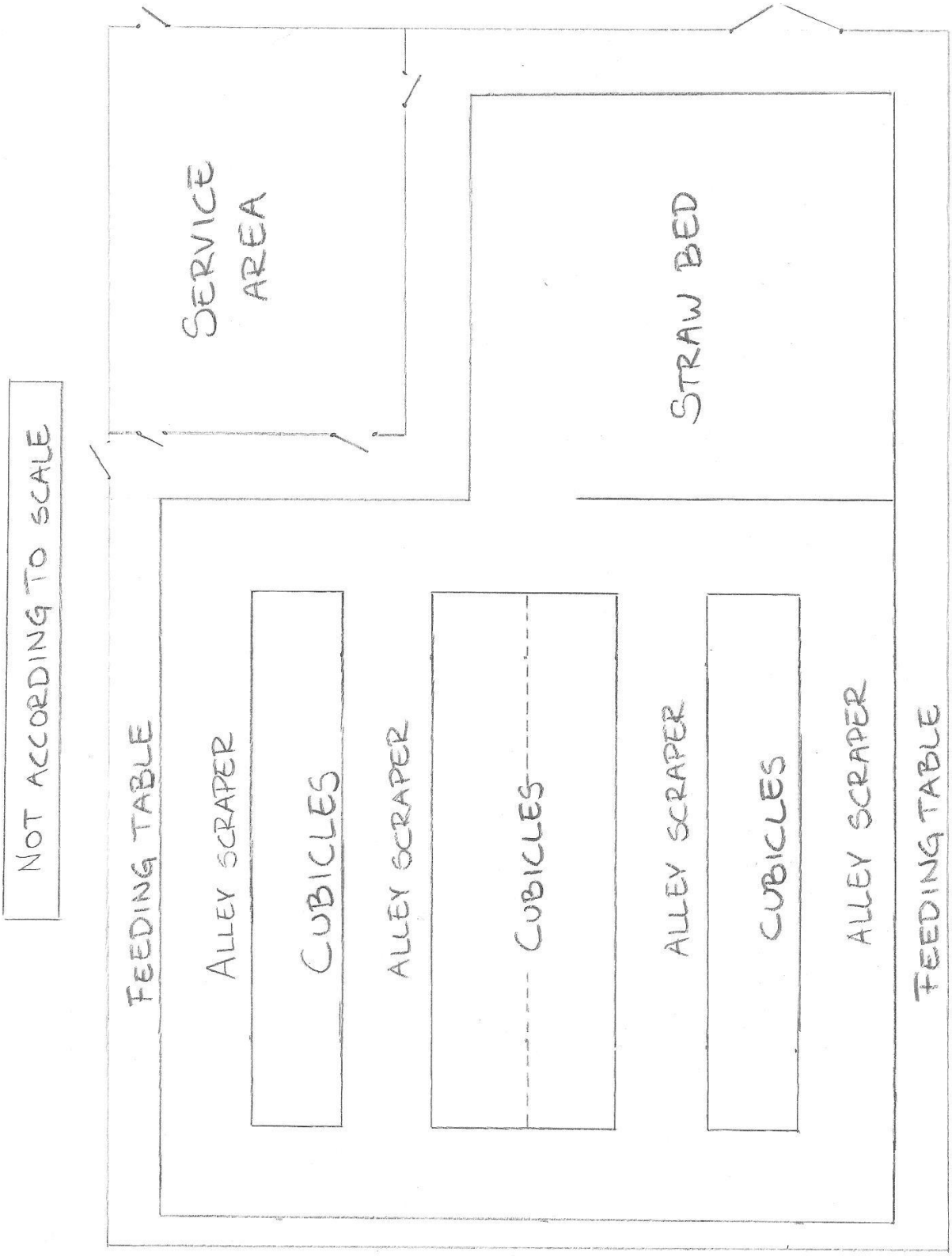


## Appendix 2 – Stable drawing



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