Assessment of Daily Behavioral Activity Patterns using Electronic Data Loggers as Predictor of Parturition, Dystocia and Metritis in Lactating Holstein Cows

THESIS

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Abstract

Dystocia and metritis in dairy cows increase the risk for health disorders and mortality, and reduce performance (milk yield, and reproductive performance). The objectives of the present study were to assess the effect of (1) parturition and (2) two calving-related events (dystocia and metritis) on behavioral activity beginning 4 d before calving and clinical diagnosis, respectively. Activity data were collected from 147 Holstein cows housed in free-stall barns from 3 dairy herds. All cows were housed in similar facilities using a close-up pen 21 d prior to the expected calving date and moved into a contiguous individual maternity pen for parturition. Electronic data loggers (IceQube™, IceRobotics, Edinburgh, Scotland, UK) were placed on the hind leg of periparturient dairy cows at 7 ± 3 d prior to the expected calving date and removed at 14 ± 3 DIM. The number of steps (n/d), standing time (min/d), number of laying bouts (n/d), and mean duration of LB (min/b) were recorded. Calving ease (CE; scale 1-4), parity, calving date and time, and stillbirth (born dead or died within 24 h) were recorded. For parturition and dystocia analyses, unassisted cows (n = 132; CE score of 1) were compared to assisted cows (n = 15; CE scores of 2-3). For the metritis analysis, cows with metritis (n = 15) were matched by parity with non-metritis cows (n = 15). Data were analyzed using MIXED (activity patterns) and GLIMMIX (stillbirth) procedures of SAS. Activity patterns were adjusted for the effect of herd, parity, and CE. Cows with unassisted birth had increased number of steps (P < 0.05) and decreased standing time (P
< 0.05) with more LB of shorter duration (P < 0.05) 24 h prior to calving. Additionally, cows with assisted births had increased number of steps and LB (P > 0.05), but LB of longer duration (P < 0.05) 24 h prior to birth compared to unassisted cows. Metritis cows spent more time standing, had fewer steps and LB, and LB of longer duration 1-3 d prior to diagnosis compared to non-metritis cows (P < 0.05). These findings provided evidence that cows experiencing parturition as well as dystocia or metritis showed distinct behavioral activity patterns at least 24 h prior to calving or diagnosis. The potential benefits of electronic data loggers (as precision management tool around the time of calving) to predict parturition, difficult births or cows at risk of metritis in real-time and around-the-clock would allow dairy producers and their personnel to improve the overall survival and welfare of cows and calves.
I dedicate this thesis to my entire family.

Especially to my parents, Gary and Marianne, and to my dear sisters, Katie, Miranda, and Jenna, and all of blessings they have brought into our lives.
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Chapter 1

Introduction

Transition cow diseases predominately occur during the first month after calving (LeBlanc et al., 2006). Strategic management practices during the transition period defined as three weeks prior to and three weeks post calving are paramount to prevent these diseases and support the transition of parturient cows into a healthy and productive lactation. A smooth transition from the dry period into lactation is of the utmost importance for animal welfare and the economic success and sustainability of dairy herds (Deluxker et al., 1991; Gearhart et al., 1990; Lucy et al., 2011). The physiologic demands of late gestation; the process of parturition and the subsequent onset of lactation; sudden changes in diet formulation (i.e., feed availability in the feed bunk), and frequent cow moves (from one pen to another) all serve as stressors that impair the ability of cows to maintain homeostasis, remain healthy, and have a productive lactation.

Dystocia and metritis are common disorders that affect dairy cows at parturition and within 21 days post-calving with a significant negative impact on survival, health and profitability of herds (Bartlett et al., 1986; Overton and Fetrow, 2008). Dystocia has been defined as an abnormal or difficult birth at any stage in labor (Schuenemann et al., 2011). The USDA’s (2010) National Animal Health and Monitoring System (NAHMS) reported that 18.6% of first-calf heifers and 10.8% of cows experience dystocia. Metritis is defined
as the inflammation of all layers of the uterus and is characterized by fetid red-brown uterine discharge with systemic signs of illness (i.e., fever, decreased milk yield, and DMI) usually within 21 days postpartum (Sheldon et al., 2006; Dubuc et al., 2011b). Metritis affects about 20% of lactating dairy cows, with a prevalence ranging from 8% to greater than 40% (Sheldon et al., 2006; Huzzey et al., 2007; LeBlanc et al., 2002; Dubuc et al., 2010; Dubuc et al., 2011ab).

It is well known that dystocia and metritis have a negative impact on reproductive performance (i.e. increased days open, increased days to first service, and increased services per pregnancy), milk yield (Dubuc et al., 2011b), and the calf survival and well-being of calves (Schuenemann et al., 2013; Barrier et al., 2012a). Difficult calvings and increased days open increased the hazard of culling (de Vries et al., 2010). Furthermore, cows that experience dystocia are at an increased risk to develop metritis and other metabolic diseases (i.e., ketosis, DA) which further affect milk yield, fertility, and survival (Sheldon et al., 2006; de Vries et al., 2010). It is well understood that calves that experience dystocia can suffer from prolonged hypoxia and acidosis; these conditions can result in immediate death (stillbirth) or reduced long-term performance and survival (House, 2002; Lombard et. al., 2007)

The identification of sick cows on dairy farms is performed by monitoring the clinical signs by farm personnel (Schuenemann et al., 2011); therefore, treatment is not provided until the clinical signs are observed. Typically, early treatment intervention is related to the success of therapeutic strategy. Identifying cows in need of medical
attention before the onset of clinical signs may be an opportunity to improve animal welfare and prevent economic losses associated with disease.

It has been suggested cows in need of medical attention may have altered activity, milk yields, and feeding patterns as general sickness behavior includes lethargy, decreased milk production, and anorexia (Mottram, 1997, Fleischer et. al., 2001; reviewed by Dantzer and Kelley, 2007; Proudfoot et al., 2009). Proudfoot et al. (2009) showed that cows experiencing dystocia are more restless 24 hours prior to calving compared to eutocic cows. Cows with metritis become depressed and consequentially less active (Huzzey et al., 2007). Electronic data loggers from various systems are already in use in commercial dairy farms and serve as the major source of data for large herds (Edwards and Tozer, 2004; Auniger et al., 2012). The development of an electronic data system that can accurately measure cow activity in real-time and around-the-clock may provide an opportunity to identify cows that need medical attention. Simply evaluating cow health on the sole basis of clinical disorders underestimates the opportunity to minimize production losses and prevent progression of subclinical disease. Using electronic data loggers to monitor cow activity patterns around-the-clock may allow for early identification of cows in need of assistance; thus, improving survival, milk yield, and reproductive performance of dairy cows.
Chapter 2

Literature Review

2.1. Eutotic Parturition

2.1.1. Stages of Parturition

The first stage of parturition is termed the dilation phase and is characterized by cervical dilation. Uterine contractions begin in this phase but abdominal contractions are not yet evident. Restless behavior (e.g., increased time walking, increased transitions from lying to standing) has been observed during this phase and could be due to the discomfort caused by uterine contractions. Behaviors observed during stage 1 include olfactory ground checks, nest building behavior, vocalization, licking themselves, discharge of feces, and tail raising (Wehrend et al., 2006; Miedema et al., 2011b; Schuenemann et al., 2011). Certain behaviors such as tail raising, restlessness, and vocalization can extend into stage 2 of labor. The completion of Stage 1 occurs when the cervix is fully dilated (Noakes et al., 2001; USDA, 2010).

Stage two of parturition is termed the expulsion phase. This phase begins with the appearance of the amniotic sac. The uterine contractions from phase 1 continue along with the onset of notable abdominal contractions. In a recent observational study by Schuenemann et al. (2011), multiparous cows were observed to begin lying down at the onset of the abdominal contractions and remained recumbent throughout calving. Conversely, they observed primiparous cows exhibiting restless behavior characterized
by increased frequency of lying to standing transitions at the beginning of phase 2 followed by a recumbent position until expulsion. Throughout the second phase, the calf continually progresses through the birth canal. In a eutotic calving clear progress should be made every 15-20 minutes starting with the feet appearance first, followed by the nose, head, trunk, and hind legs outside of the vulva (Schuenemann et al., 2011). Passage of the head and shoulders is the most strenuous part for the dam. Once the head and shoulders are outside of the vulva approximately three intense abdominal contractions will complete the birth (Schuenemann et al., 2011). Stage 2 of parturition is complete upon delivery of a single or multiple calves.

The third and final stage of labor is termed expulsion of the fetal membranes. This phase is characterized by passage of the fetal membranes within the first 24 hours after birth (Kelton et al., 1998; reviewed by LeBlanc et al., 2008)

2.1.2. Eutotic Parturition Behavior

The behavioral changes associated with parturition have been well described (Mee, 2004; Wehrend et. al., 2006; Miedema et. al., 2011ab). The onset of parturition is characterized by many behavioral variances in a cow’s normal behavioral pattern (Wehrend et. al., 2006; Miedema et. al., 2011ab). Behavior such as eating, ruminating, and grooming decrease as the process of parturition approaches (Huzzey et al., 2007). Udder distension, colostrum dripping, liquefaction of the cervical plug, vaginal discharges, anorexia, and seeking isolation were observed within 36 hours prior to
calving (Mee, 2004). Signs of imminent birth within 12-24 hours include frequent transitions between standing and lying positions, shifting weight, urinating and defecating, swishing or raised tail, vulvar swelling and relaxation, teat distension, and relaxation of the pelvic ligament (Mee, 2004). On the day of calving, periparturient cows show a restless behavior such as increased number of lying bouts (Huzzey et al., 2005). Restlessness behavior is characterized by an increase in the number of transitions between standing and lying as well as an increase in time spent walking or number of steps (Wehrend et al., 2006). Changes in tail position, postures, and licking the ground become more frequent immediately prior to parturition and during labor (Wehrend et al., 2006). Miedema et al. (2011b) conducted a study that compared the behaviors of dams at calving with that of pre-calving dams (served as controls). It was concluded that the number of lying bouts, frequency of tail rising, and duration of ground licking were significantly higher in dams during parturition compared to control cows (Miedema et al., 2011b). Average daily lying duration was significantly lower in dams during parturition than control cows. The same study also compared behaviors during calving in 6 hour intervals. The number of lying bouts during the six hours prior to calving was significantly higher compared to the previous 6-hour periods (-24, -18, and -12) while duration and frequency of walking showed no significant differences. Additionally, heifers may exhibit unique changes in behavior at calving compared to cows because they have never experienced calving before. In a study by Wehrend et al. (2006), 32% of multiparous cows were classified as calm compared to 0% of primparous cows. Using
sensors that recorded the number of steps, lying time, and number of lying bouts, a decrease in lying time per day on the day before calving was observed (Maltz and Antler, 2007). Until recently, most of the studies describing behavior at calving are observational in nature with the use of video cameras or on-site observation to record changes (Mee, 2004; Wehrend et al., 2006; Proudfoot et al., 2009; Schuenemann et al., 2011). The development of electronic activity monitoring systems allows the capture of cow activity patterns around-the-clock.

2.2. Dystotic Parturition

2.2.1. Definition and Prevalence of Dystocia

Dystocia has been defined as delayed or difficult parturition at any stage of labor (Mee, 2004; Schuenemann et al., 2011). In the UK, bovine veterinary practitioners ranked dystocia as a painful conditions experienced by cows and heifers (Huxley and Whay, 2006). Dystocia results in pain and distress which compromises animal welfare of the dam and calf; leading to economic losses due to increased mortality and decreased productivity (long term survival, fertility, and milk yield; Olentacu et al., 1988; Huxley and Whay, 2006).

Dystocias can be further classified by the degree of assistance required using a scale 1 to 3 or 1 to 5 (1 = no assistance, 2 = assistance by one person, 3 = assistance by two people, 4 = use of mechanical traction, and 5 = surgical procedure; Lombard et al., 2007; Schuenemann et al., 2011). The reported prevalence of dystocia varies widely nationally
and internationally. In a review by Mee (2008), it was reported that while in most countries dystocia prevalence is between 2% and 7%, U.S. dairy herds reported a prevalence of around 13% (Reviewed by Mee, 2008). It is well known that dystocia is more common among primiparous cows. First-calf heifers had approximately three times greater risk to experience dystocia compared to multiparous cows (Mee, 2004). Meyer et al. (2001) evaluated 666,341 dairy calving records and estimated 28.6% dystocia prevalence for primiparous and 10.7% for multiparous cows. Additionally, ranges of dystocia from 18.6% to 28.6% for primiparous and 10.7% to 12.7% for multiparous cows have been reported (Meyer et al., 2001; USDA, 2010).

As production dairy systems concentrate in large operations, dairymen rely more heavily on production records of the whole herd for decision making compared to individual cow observation. Therefore, identification of cows in need of assistance at calving, diagnosis of diseases, and management of pain (due to distress and illness) are a challenging task for farm personnel. Calving-related losses (survival, health, and productivity) and welfare practices have become known challenges for the dairy industry worldwide; and management practices have been associated with this problem.

2.2.2. Causes of Dystocia

Dystocia may be caused by failure of expulsive forces, lack of dilation of birth canal, and fetal mismatch and position (Noakes et al., 2001). The most common cause of dystocia in primiparous cows is associated with feto-pelvic mismatch followed by
abnormal position of the calf (Reviewed by Mee, 2008). In multiparous cows, malposition of the calf is the most common cause of dystocia followed by feto-pelvic mismatch, multiple calves (twins or triplets), uterine inertia, uterine torsion, and cervical stenosis (Reviewed by Mee, 2008).

Feto-pelvic mismatch is the most common reason for dystocia in dairy cattle and is also the most prevalent indication for a cesarian section to be performed (Reviewed by Mee, 2008). The primary determinants of this form of dystocia is calf weight, most importantly, and also dam pelvic size. As a result of the higher birth weights (1-3 kg) of male calves they are 25% more likely to experience this form of dystocia than female calves (Johanson and Berger, 2003).

Malposition of the fetus at delivery can cause calving difficulty or dystocia. Normal presentation of the calf is, anterior, dorsal-sacral, and longitudinal with the head and legs extended. The most common abnormal presentation is posterior, or breech, followed by foreleg malposture and cranial malposture (Noakes et. al., 2001). The prevalence of fetal malposition is low (<5%; Mee, 1991ac); however, it is the most common cause in multiparous cows (accounting for 20-40% of the cases; Meijering, 1984).

Incomplete dilation of vulva or cervix causes inadequacy of the birth canal and leads to calving difficulty. Vulval stenosis is more common in primiparous cows whereas cervical stenosis is more common in multiparous cows. Assisting before the dam is dilated can iatrogenically cause this form of dystocia. Incomplete dilation has been
associated with confinement periparturient environment, early obstetric intervention, and hormonal asynchrony prior to calving (Reviewed by Mee, 2008).

Less common causes of dystocia include twin calvings, uterine inertia, and uterine torsion. Risk factors for a twin calving include parity, season, herd, previous twinning, high DMI, and high milk yield (Mee, 1991b; reviewed by Mee 2008). Uterine inertia is a lack of sufficient myometrial contractions to expel the fetus and can be classified as primary or secondary. Uterine inertia is classified as secondary when the inertia is due to the prolonged calving from another form of dystocia. It is not the cause of the dystocia itself put perpetuates and complicates the calving. It is classified as primary uterine inertia when there is a non-dystocia related issue causing uterine inertia resulting in a failure of expulsive forces that in turn causes the dystocia. The cervix will be fully dilated but the weak myometrial contractions are not strong enough to expel the fetus. Causes of primary uterine inertia include milk fever, lack of exercise, twins, and preterm calving. Uterine torsion is the twisting of the uterine body. It is expected when a cow is in labor and there are no signs of the fetus coming from the vulva and is confirmed by palpation. Excessive fetal movement during calving and mechanical factors such as a slip or fall has been suggested as potential causes (Frazer et al., 1996; Noakes et al., 2001). Precipitating factors include debility, insufficient exercise, and fetal oversize (Frazer et al., 1996; Noakes et al., 2001). Uterine torsion is an uncommon cause of dystocia accounting for less than 5% of dystocia cases (Frazer et al., 1996).
2.2.3. Effects of Dystocia on Dams and Calves

Dystocia has both welfare and economic impacts on dairy herds. The effects of a dystocia on both the dam and calf are well known. Physiologically, a calf experiencing a dystocic birth may suffer from an extended period of hypoxia. This can be immediately fatal (stillbirth) or reduce long term survival and performance (Breazile et al., 1988; House, 2002). Lombard et al. (2007) showed that calves who survived dystotic births were often slow to stand and suckle. Dystocia has also been shown to negatively affect absorption of colostral immunoglobulins in calves (Odde, 1988). Therefore, calves that survive dystocia had increased risk for disease and mortality within thirty days of calving (Mee, 2004; Lombard, 2007).

According to Mee (2004), dystocia and perinatal mortality are frequently interrelated. A significant loss associated with dystocia is stillbirth; which is defined as a calf born dead (normal gestation length) or that dies within 24 hours after calving. Martinez et al. (1983) reported 5% increase in cow deaths and a 53% increase in calf losses as dystocia scores increased from 1 to 5. Tenhagen et al. (2007) reported that the proportion of dead calves was significantly higher in moderate or severe dystocic births as well as for twin calves. Mee (2004) reported that necropsy revealed 75% of all peripartureint calf deaths occurred within 1 hour of calving; 10% prepartum, 15% postpartum, meaning that 90% of the calves are alive at the start of parturition process. Therefore, a large portion of these deaths are preventable and reducing these calving-related losses would increase profitability and welfare of dairy herds. Stillbirth can be
managed and prevented by frequent and thorough observation during calving (Schuenemann et al., 2011; 2013).

Dystocia negatively affects both the welfare of the dam and her productivity (Fourichon et al., 1999; 2000; Gundelach et al., et al., 2009). Dystocia has been suggested to be one of the most painful conditions for a dairy cow (Huxley and Whay, 2006). Dams that experienced dystocia had reduced milk yield, increased risk for metritis, and rebreed later than unassisted cows (Lombard et al., 2007). Dystocia has been demonstrated to significantly affect the dam’s subsequent reproductive life partially due to the trauma to the dam’s reproductive tract (Sheldon et al., 2006). Fertility following a dystocia is decreased as dams with dystocia have increased days to first estrus, increased days to first service, and increased services per conception (Dematawewa and Berger, 1997). Cows experiencing severe dystocia take longer to conceive and more likely to be open by 200 DIM compared to unassisted cows (Tenhagen et al., 2007). Additionally, dystocic births delayed uterine involution and the onset of luteal activity postpartum with abnormal progesterone profiles (Dobson et al., 2001). These reproductive losses result in economic losses to the producer and increased likelihood of early removal of cows from the herd (Tenagen et al., 2007; de Vries et al., 2010). Dystocia also increase the risk of other diseases such as retained placenta, mastitis, and hypocalcemia (Oletnacu et al., 1988; Lombard et al., 2003; Lombard et al., 2007); all of which can further contribute to reduced milk yield, reduced fertility, increased risk for culling or mortality (Mee, 2004).
Tenhagen et al. (2007) reported that both mild and severe cases of dystocia had no effect on milk production which corresponded with the findings of Lucey et al. (19864). However, Dematawewa and Berger (1997) reported considerable milk loss for cows experiencing dystocia as opposed to eutocic births (Djemali et al., 1987). Rajala and Grohn (1998) attributed these varying reports to the different approaches used to evaluate milk yield. Some studies focused on entire lactation (305 day milk yields) which can dilute the short term decreases. Rajala and Gröhn (1998) also noted that there were probably discrepancies due different statistical methods, milk measures, varying definitions of dystocia, and whether or not effects of other diseases were accounted for in the analysis. Lombard et al. (2003) and Rajala and Gröhn (1998) found that effects of dystocia on milk production varied with parity and yield, the greatest milk losses seen in early lactation when production is high. Overlooking these factors could have contributed to the conclusions that dystocia had no effect on milk yield. They found no impact of dystocia on milk yield for primiparous cows. Decreased yield was seen in multiparous cows by 2.2 kg/d during first 2 weeks of lactation. However, when separated by milk yield, lower producing cows showed no effect and in high producing cows milk yield decreased an average of 4.9 kg/day for the first 2 weeks of lactation. While Dematawewa and Berger (1997) found primiparous cows experienced highly significant losses of 305 d adjusted milk. Another study showed that milk losses early in lactation may be associated with pain and lesions associated with dystocic births (Wehrend et al., 2006) and the subsequent increased risk for metritis (Oltenacu et al., 1990; Rajala and Gröhn, 1998).
When considering milk losses, it is important to remember that all transition cow diseases are interrelated and predispose the dam to other diseases (Deluyker et al., 1991). The milk losses from these diseases are also interrelated and in some dams the production loss cannot be solely attributed to dystocia (Rajala and Grohn, 1998). For instance, cows with dystocia resulted in high risk for retained fetal membranes and metritis, which has been documented to have a significant negative effect on milk yield (Lucey et al., 1986; Rajala and Gröhn, 1998). Therefore, even though it is inconclusive how significant milk losses from dystocia alone are, it can be concluded that based on the increased risk for other diseases dystocia plays a critical role in cow health and in the onset of lactation performance.

In the U.S., it is estimated that dystocia costs the beef and dairy cattle industries more than $400 million annually (USDA, 2010). Olentacu et al. (1988) estimated that the total costs of dystocia, including its sequela, are four times greater than the cost of treatment alone. Costs of dystocia come from increased cow and calf morbidity and mortality (i.e., culling) and production losses, both reproductive and yields. The cost per day open was estimated to be $1.99-$3.00 while the cost for each extra AI service was $15 (Olentacu et al., 1988). Additionally, the cost of dystocia is influenced by parity and was estimated at $1,200, $1,000, and $600 for first, second, and third or greater lactations, respectively (Olentacu, 1988). There is also the cost of the loss of calf or decreased productive life of the calf (Dematawewa and Berger, 1997) costs tends to increase with the severity of the dystocia.
2.2.4. Behavior of Dystocic Parturition

During parturition, higher proportions of cows experiencing dystocia were found to rub against walls, discharge urine, and scrape the floor compared to eutocic births (Wehrend et al., 2006). Additionally, cows with dystocia had more standing bouts and spent less time eating 18 hours before calving (Proudfoot et al., 2009). Furthermore, assisted cows showed more restless behavior (lying bouts and transitions) compared to eutocic births (Schuenemann et al., 2011). Assisted births had more time lapse from the amniotic sac or feet appearance of the calf outside the vulva to birth (Schuenemann et al., 2011). The estimated reference time from the appearance of the amniotic sac or feet of the calf outside the vulva to birth were approximately 70 and 65 min, respectively (Schuenemann et al., 2011). NAHMS reported 95% of surveyed dairy operations assisted within 3 hours of the amniotic sac appearing outside the vulva (USDA, 2010). In another study, an assessment of cow behavior showed that cows experiencing dystocia consumed 12% less dry matter (DM) than cows with eutocic birth and 24% less DM 24 hours before calving (Proudfoot et al., 2009). In a study by Metz and Metz (1987) dystocia was preceded by a period of unrest characterized by frequent changes between standing and lying positions and interrupted feedings. These studies suggest that cows that experiencing dystocia showed a unique behavioral patterns before calving. Recognizing early signs of dystocia prior to birth would help calving personnel identify those cows at risk and pre plan a triage as opposed to waiting for the signs of intervention.
(Schuenemann et al., 2013) with the subsequent positive management impact on the overall calf-cow survival and welfare.

2.2.5. Prevention of Dystocia and Metritis

In order to prevent or reduce the prevalence of dystocia, the risk factors for dystocia and metritis must be controlled. Mee (2004) named five critical periods during which action can be taken to prevent dystocia which are discussed here. The first area for prevention is at the heifer’s birth. Heifers from dams with a history of dystocia, twining, milk fever, or heavy birth weights should not remain in the herd. Heifers born late in the season are also at risk in seasonal calving operations as they will be too small at the time of breeding and as a result should not be retained in the herd. The next control point is pre-service. Heifers should be at 65% of their body weight to ensure adequate pelvic size at delivery and sires with ease calving should be used to reduce the probability of dystocia. The next opportunity to prevent dystocia is during pregnancy by accurately detecting twins by 50-80 days and determining gender at 55-65 days you can identify at risk dams and use appropriate intervention when applicable (Mee, 2004). Ensuring adequate weights at pre-calving is the next area for dystocia control. An adequate body weight, approximately 85% of the mature body weight, and having a body condition score of 3.75 at calving will prevent dystocia due to feto-pelvic mismatch (Mee, 2004). Having appropriate nutrition management during the dry period helps control body condition scores. Moving dams to individual maternity pen (primiparous and multiparous
cows) separately reduces stress at the time of calving (Mee, 2004). Good calving management such as using deep straw bedding and ample of space in the maternity pen can also aid in reducing periparturient stress (Mee, 2004). The last control point to prevent dystocia is during calving. By providing good maternity pen supervision calving progress can be adequately monitored. Detection of a lack of appropriate progress will allow for timely intervention in prolonged calving and prevent secondary uterine inertia (Mee, 2004).

Control of frequency of dystocia on dairy herds depends on selections of calving ease sires and calving personnel education. At the herd level sire selection, heifer growth (breeding heifers at the appropriate body weight), periparturient management, and veterinarian led investigations of high dystocia prevalence herds all play a role in reducing the prevalence of dystocia within herds. For instance, breeding strategies that uses ease calving sires can greatly reduce the frequency of dystocia caused by feto-pelvic mismatch. However, even with the best breeding strategies, dystocia will still occur due to other non-preventable causes such as mal-positioning and uterine torsion. For that reason, identification and appropriate intervention of dystoica in a timely manner is necessary for positive outcomes.
2.3. Management of Parturition

2.3.1. Parturition Management Practices

Although most cows will experience unassisted births, in case of dystotic birth human intervention is rendered. By monitoring cows as they go through the stages of calving, cows experiencing problems can be identified and appropriate intervention can be carried out by on-farm personnel. Management of calving is often performed by visual observation of cows in the close up pen for signs of imminent birth, and when needed (e.g., lack of progress) appropriate intervention minimizes negative effects and outcomes for the dam and calf.

Ideally, heifers and cows in the close-up pen would be observed at all times; however, this practice is not possible or practical on most dairy farms. The USDA’s (2010) NAHMS survey of dairy operations concluded that close-up animals were observed more frequently during day than at night. During day time, 47.2% of the operations monitored cows every 3 or less hours while 17.6% monitored cows every 5 hours. At night, only 17.7% of the dairy operations monitored pre-partum cows every 3 or less and 53.9% every 5 or more hours. For unassisted calving, the average time from appearance of the amniotic sac or feet of the calf outside the vulva to the birth is 70 or 65 min, respectively (Schuenemann et al., 2011); thus, the risk for late intervention increases as frequency of observation decrease during the day and night shifts. Training on calving management for dairy personnel has been reported as a top priority to mitigate the negative effects of dystocia (Lombard et al., 2007) and to reduce the prevalence of
stillbirth (Schuenemann et al., 2011; 2013). Under field conditions, calving personnel should be able to recognize the stages of parturition, signs of imminent birth, when and how to intervention, and follow established frequency of observations (Schuenemann et al., 2013).

Monitoring the behavioral signs of stage I (i.e., walking, tail raising, increased frequency of standing and lying transitions) and reference landmarks during stage II such as appearance of amniotic sac or feet outside the vulva (i.e., abdominal contractions) with calving progress every 15-20 min should be used a guidelines to determine the time for intervention in cows experiencing difficult births (Mee, 2004; Mee et al.;, 2011; Schuenemann, et al., 2011; 2013). Mee (2004) described that delayed intervention will prolong the duration of stage II and reduce perinatal vitality and subsequent fertility of dams. However, when a malposistion is evident (e.g., only one foot is visible of the calf outside the vulva) assistance should be provided immediately (Schuenemann et al., 2011). It has been suggested that the stress of a prolonged deliver rather than the type of assistance may ultimately be responsible for reduced calf vigor following dystocic birth (Mee, 1991a).

2.3.2. New Methods for Parturition Management under Investigation

As farms grow in size, the number of employees per cow is decreasing and hence the ability to visually asses calving in individual cows is becoming more difficult and less effective. Automated monitoring systems such as electronic pedometers and necklaces
are becoming more popular on-farms to predict estrous detection, rumination, and feeding time as well to monitor health events (Ledgerwood et al., 2010; Müller and Schrader, 2003; 2005; Urton et al., 2005). Parturition has been recognized among the most suitable health events for electronic monitoring systems (Motttram, 1997).

It is known that cow behavior changes as parturition approaches (Miedema et al., 2011b; Barrier et al., 2012b). Because of the behavioral variations at the onset of parturition, electronic data loggers may serve as a robust system to predict parturition and other health events in dairy cows. These devices may help bridge the gaps for personnel compliance and aid in timely intervention. Not only could monitoring activity allow prediction of onset of calving, but also difficult births (dystocia; Midema et al., 2011b). If warning signs of difficult births or transition cow diseases (e.g., metritis) could be predicted, it would allow dairy personnel to triage cows in need of assistance in a timely manner as opposed to waiting for the clinical signs (Hodge et al., 1982). Appropriate management at calving and throughout the transition period is paramount for successful performance of calves and lactating dairy cows. The use of electronic data loggers to monitor transition cows may reduce calving-related losses and improve welfare of cattle.

2.4. Sickness Behavior in Dairy Cattle

2.4.1. Physiology of Stress and Sickness Behavior

Sickness behavior has been defined as discomfort, uneasiness, lack of energy, fatigue, loss of appetite, muscle and joint pain, and fever in an individual (Aubert, 1999;
Reviewed by Dantzer and Kelley, 2007). These non-specific clinical sings appear with a wide variety of illness and are not pathogen or injury specific. They reflect the body shifting its priorities from maintenance behaviors to those that aid in fighting off invaders and repairing tissues. When the body experiences an insult, either by a pathogens or tissue trauma, the immune system is activated (Tizard, 2009b). The pathway is initiated by alarmins released from damaged tissues or by a pathogens specific pathogen associated molecular pattern (PAMP) being recognized by the toll-like receptors (Tizard, 2009a). Both of these inflammatory stimuli stimulate the local sentinel phagocytic cells to release pro-inflammatory cytokines such as IL-1, IL-6, and TNF which go into circulation and diffuse into distal tissues to induce neurologic, metabolic, and endocrine changes (Tizard, 2009a). These cytokines signal the brain by two pathways: (1) via the neurons that supply the damaged tissue (IL-1 receptors on the sensory nerve fibers of the vagus nerve which transmits the signal to the brain) and (2) involves the cytokines entering the circulation and diffusing into the brain or stimulating production of more cytokines in the brain (Tizard, 2009b). The end result of both pathways is signaling the brain to activate and inhibit specific neuron populations to induce a physiologic response to restore health during illness (Hart, 1988, reviewed by Dantzer and Kelley, 2007)

The brain responds to these signals in many ways with the most clinically apparent signs being sickness behavior (manifestation of clinical signs) and fever. The cytokines signal PGE2 production in the brain which acts on the pre-ventricular nucleus of the hypothalamus to raise the body temperature (Tizard, 2009b). Fever enhances the
functional activity of immune cells and reduces the growth rate of bacterial pathogens (Mackowiak, 1981; Larson and Dunn, 2001). In order for an animal to increase its body temperature by 1 degree Celsius its metabolic energy demand increases 13% (Aubert, 1999). It is believed that this is the reason behind other energy saving and heat loss minimizing sickness behaviors such as lethargy.

Additionally, IL-1 acts on the brain to signal a reduction in social behavior by stimulating the release of sleep-inducing molecules (Tizard, 2009b; reviewed by Dantzer and Kelley, 2007) Lethargy, a common clinical sign of illness, allows an individual to conserve energy to support the high metabolic demands of fever and increase efficiency of defense and repair mechanisms (Johnson, 2002). Another effect of IL-1 on the brain is hunger suppression, of which the benefits are unknown other than energy conservation (Tizard, 2009b). Overall, there is a shift from normal behavioral activities such as walking and eating to alternative behaviors that require less energy (Johnson 2002; reviewed by Dantzer and Kelley, 2007; Fogsgaard et al., 2012). This strategy supports the metabolic and physiological changes of infected individuals. This has been demonstrated in studies showing decreased rumination, feeding time and dry matter intake, and changes in resting behavior in sick animals (Siivonen et al., 2011; Fogsgaard et al., 2012) or experiencing difficult births (Barrier et al., 2012b).
2.4.2. *Activity Monitoring Systems to Predict Parturition and Sickness Behavior*

For most dairy operations, the diagnosis of dystocia and postpartum diseases such as metritis and DA requires skilled personnel (good clinical eye) and time (monitoring of all pre- and post-fresh cows). The identification of sick animals relies on the accurate measurement of body temperature by transrectal thermometers. Although rectal body temperature is widely used to identify sick animals (especially during the transition period), it is influenced by type of thermometer or procedure itself (Burfeind et al., 2009), parity, month of calving, and type of disease diagnosis (Wenz, et al., 2011). Measuring cow activity may have a positive management (compliance) and economic impact by effectively identifying cows in need of medical attention under field conditions. For sick animals, the pattern of cow activity changes before the appearance of clinical signs; therefore, making it a robust parameter to monitor the overall health status of cows (Fogsgaard et al., 2012).

The technology to monitor cow behavioral activity (e.g., Select Detect™, AfIMILK™) or rumination (e.g., RuminAct™) is available for health (Chapinal et al., 2011) and reproductive programs in dairy cattle (Aungier et al., 2012). Recently, remote alarm systems such as an intravaginal insert device that is activated during stage II of labor (Palombi et al., 2013) and electronic data loggers (IceQubes; IceRobotics, Scotland, UK) to assess behavioral changes prior to parturition (Titler et al., 2013ab), metritis diagnosis (Titler et al., 2013c), standing behavior for hypocalcemic cows (Gemini Dataloggers Ltd., Chichester, UK; Jawor et al., 2012) have been investigated.
2.5. Statement of the Problem and Rationale

Prevention of disease at the herd level requires an ongoing and constant effort with effective coordination of the whole system (animals, environment, and personnel). Substantial knowledge exists to prevent many diseases or conditions; however, it must be translated into on-farm applications or practices to have a measurable effect at the herd level. Calving-related losses (survival, health, and productivity) and welfare practices have become known challenges for the dairy industry worldwide; and management practices have been associated with this problem. Calving-related losses due to dystocia and metritis significantly affect herd productivity and profitability through decreased milk production, extended days open, and increased replacement costs (Rajala-Schultz and Gröhn, 1999ab; Groenendaal et al., 2004; Meadows et al., 2005; de Vries, 2006).

Management of transition cows is paramount for the economic success and sustainability of dairy herds. It is well known that periparturient diseases or conditions such as dystocia and metritis have a negative impact on milk yield, reproductive performance (LeBlanc et al., 2002; Dubuc et al., 2010), and overall animal well-being. Also, periparturient cows need close monitoring to ensure prompt intervention and to minimize the negative effects of dystocia on the calf’s and cow’s health. Cows that have dystocia are more likely to develop metritis and other metabolic disease such as ketosis and DA, which affect milk yield, fertility, and survival (Sheldon et al., 2006; de Vries et al., 2010). Dairy cows that have dystocia or that developed metabolic or infectious diseases postpartum might have altered activity patterns (e.g., feeding time). For instance,
cows with dystocia are more restless 24 hours prior to calving than cows with normal calving (Proudfoot et al., 2009). On the other hand, cows with metritis may become depressed and consequentially less active; reducing feeding time (Huzzey et al., 2007). For dairy operations, the identification of these conditions requires time and attention to details from skilled veterinarians and well-trained personnel.

The development of electronic systems that accurately measure walking activity of dairy cows (in real-time and around-the-clock) within a herd provide a clear opportunity to identify individual animals in need of medical attention. According to the Ohio Livestock care Standards “Livestock must also be monitored regularly for evidence of disease, injury and parasites and if evidence of any of these ailments is found, corrective measures must be taken” (Livestock Care Standards, 2011). Evaluating transition cow success only on the basis of clinical disorders substantially underestimates the opportunities for superior transition management. Being able to provide care to cows in need of medical attention in a timely manner is important for survival (i.e., response to therapy and recovery), subsequent milk yield, and reproductive performance. Monitoring cow-activity would allow dairy producers and their veterinarians to improve the overall herd performance (health and productivity) by improving animal care, reducing the risk of culling and/or mortality (e.g., due to late interventions), and reducing replacement costs. Practicing dairy veterinarians and dairy producers have expressed strong support for this approach. The technology to monitor cow-activity is available for reproductive programs in dairy cattle (e.g., Select Detect™, AfiFARM™). Using data loggers
(IceQubes; IceRobotics, Scotland, UK) to monitor cow-activity around the clock, our preliminary data showed a distinct cow-activity behavior (less steps and lying bouts) in cows experiencing dystocia starting at 24 hours prior to birth as opposed to normal calving. Therefore, the overall objectives of the present study were to generate research-based information on activity patterns (predictive values) of dairy cows experiencing parturition, difficult birth (dystocia), and metritis. We propose to achieve the overall objectives by pursuing the following specific aims:

I. Assess the effect of parturition and difficult births (dystocia) on cow behavioral activity 4 d before calving. The working hypothesis is that dairy cows (primiparous and multiparous) experiencing dystocia will show a distinct behavioral activity pattern when compared to unassisted dairy cows at calving.

II. Assess the effect of metritis on activity behavior 3 d before and after diagnosis in lactating dairy cows. The working hypothesis is that lactating dairy cows experiencing metritis will be less active when compared to non-metritis cows.

2.6. References


Chapter 3

Effect of parturition and dystocia on daily behavioral activity patterns prior to calving in Holstein dairy cows


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3.1. Abstract

Dystocia increases the risk for health disorders or mortality, and reduces performance of both the dam and calf. The objectives of the present study were to assess the effect of parturition and dystocia on cow behavioral activity 4 d prior to calving. A total of 147 Holstein cows (primiparous and multiparous) housed in free-stall barns from 3 dairy herds were used. All cows were housed in similar free-stall barns using a close-up pen 21 d prior to the expected calving date and moved into a contiguous individual maternity pen for parturition. Electronic data loggers (IceQube™, IceRobotics, Edinburgh, Scotland, UK) were placed on the hind leg of periparturient dairy cows at 7 ± 3 d prior to the expected calving date and removed at 14 ± 3 DIM. Calving ease (CE; scale 1-4), parity, calving date and time, and stillbirth (born dead or died within 24 h) were recorded. The number of steps (n/d), standing time (min/d), number of LB (n/d), and mean duration of LB (min/b) were recorded. Unassisted cows (n = 132; CE score of 1) were compared to assisted cows (n = 15; CE scores of 2-3). Data were analyzed using MIXED (activity patterns) and GLIMMIX (stillbirth) procedures of SAS. Activity patterns for assisted or unassisted cows were adjusted for the effect of herd, parity, and CE. Cows with unassisted birth had increased number of steps (P < 0.05) and decreased standing time (P < 0.05) with more LB of shorter duration (P < 0.05) 24 h prior to calving. Additionally, cows with assisted births had increased number of steps and LB (P > 0.05), but LB of longer duration (P < 0.05) 24 h prior to birth compared to unassisted cows. These findings provided evidence that cows experiencing difficult births showed
distinct activity behavior 1 d before calving. Recognizing early warning signs of dystocia prior to birth may help identify those cows most at risk and pre-plan a triage as opposed to waiting for the usual signs of intervention. Monitoring cow activity along with proactive management practices around the time of calving should improve the overall survival and welfare of both the dam and calf.

3.2. Introduction

Parturition is divided into 3 stages (Noakes et al., 2001; USDA, 2010) characterized by hormonal, behavioral, and physical changes (e.g. dilation of soft tissues). Under normal conditions (eutocia), it progresses gradually from one stage to the next (Wehrend et al., 2006; Miedema et al., 2011ab; Schuenemann et al., 2011) ending with the delivery of the calf (Noakes et al., 2001; Schuenemann et al., 2011). Most of the transition cow diseases (e.g., metritis, stillbirth) occur during the first month after calving (LeBlanc et al., 2006); however, pre-fresh and calving management practices have been associated with these problems (Schuenemann et al., 2011; Silva et al., 2013; Hunter et al., 2013). Under field conditions, the observation of amniotic sac (AS) or feet of the calf outside the vulva as well as calving progress are clear and concrete landmarks that calving personnel can easily identify (Schuenemann et al, 2011; 2013). These guidelines work best when calving personnel monitor periparturient cows around the clock (24 h, 7 d per week). In practice, however, the frequency of observation (calving personnel walking the pen and actually observing cows every 1 h) is critical to determine the onset
of the AS or feet of the calf outside the vulva to identify cows in need of assistance (dystocia) and reduce the prevalence of stillbirth (Hunter et al., 2013; Schuenemann et al., 2013). Therefore, development of monitoring systems that can predict parturition or cows experiencing difficult births would allow dairy producers and their veterinarians to improve the overall herd performance (health and productivity) by improving animal care, reducing the risk of culling or mortality (e.g., due to late or no interventions), and reducing replacement costs.

The prediction of parturition in cattle has been investigated using real-time ultrasound (Wright et al., 1988), changes in body temperature (Burfeind et al., 2011), blood 17-β-oestradiol profile (Shah et al., 2007), assessment of progesterone level (Matsas et al., 1992), relaxation of pelvic ligament (Dufty, 1971), electrolyte concentration in mammary secretions (Bleul et al., 2006), and video monitoring of cows prior to calving (Cangar et al., 2008). However, these management practices have not been widely adopted by dairy producers. The technology to monitor cow behavioral activity (e.g., Select Detect™, AfIMILK™) or rumination (e.g., RuminAct™) is available and used by dairy producers for health and reproductive programs in dairy cattle. Recently, remote alarm systems such as an intravaginal insert device that is activated during stage II of labor (Palombi et al., 2013) and assessment of behavioral changes prior to parturition have been investigated (Titler et al., 2013abc). Therefore, the first objective of the present study was to assess the effect of parturition on behavioral activity 4 d prior to calving using electronic data loggers (IceQube™, IceRobotics,
Edinburgh, Scotland, UK). The hypothesis was that dairy cows approaching parturition will exhibit distinct behavioral patterns (steps, standing time, LB, and duration of LB). The second objective was to assess the effect of difficult birth (assisted) on behavioral activity 4 d prior to calving using electronic data loggers (IceQube™, IceRobotics, Edinburgh, Scotland, UK). The hypothesis was that dairy cows experiencing assisted births will exhibit distinct behavioral patterns (steps, standing time, LB, and duration of LB) as opposed to unassisted cows.

### 3.3. Materials and Methods

#### 3.3.1. Animals, Feeding, and Facilities

In total, 147 lactating Holstein cows (55 primiparous and 92 multiparous) from 3 dairy farms were used in the present study. Briefly, cows were housed in free-stall barns and milked thrice daily at approximately 8-h intervals. Cows were fed twice daily, in the morning and afternoon, with a TMR formulated to meet or exceed dietary nutritional requirements for lactating and dry dairy cows (NRC, 2001). This study was conducted from July 2011 through August 2012. The procedures described below were reviewed and approved by the Institutional Animal Care Use Committee, The Ohio State University.
3.3.2. Management of Dry Cows and Calving

Every week, a list of cows was obtained based on their calving dates using on-farm computer records (Dairy-Comp 305, Valley Agricultural Software, Tulare, CA). Pregnant cows were dry ed-off 60 ± 3 d prior to the expected calving date and moved into the dry pen immediately after last milking. All cows were housed in similar close-up pens 21 d prior to the expected calving date and moved into a contiguous individual maternity pen for parturition. Cows were closely monitored by on-farm personnel for signs of parturition (appearance of amniotic sac or feet of the calf outside the vulva) every 1 h (Schuenemann et al., 2011; 2013). All calving personnel received the same training at the beginning of the study. The calving ease (CE) of cows (assistance provided at birth) were recorded using a 4-point scale (1 = no assistance provided; 2 = light assistance by one person without the use of mechanical traction; 3 = mechanical extraction of the calf with an obstetric calf-puller; and 4 = severe dystocia: surgery or fetotomy needed; Schuenemann et al., 2011). Additionally, calving date and time, and stillbirth were recorded. Stillbirth was defined as a calf born dead or died (normal gestation length) within 24 h after birth (Schuenemann et al., 2011).

3.3.3. Calcium Status of Cows

Blood samples (10 mL) for determination of serum calcium status were collected 7 ± 3 d prior to the expected calving by coccygeal venipuncture (BD Vacutainer, Franklin Lakes, NJ). Briefly, blood samples were centrifuged at 2,785 × g for 20 min immediately
after collection, and serum samples were stored at −20 °C until assayed for total calcium. Total serum concentration of calcium were determined in duplicates using a commercially available kit (Calcium Liquicolor No. 0150, Stanbio Laboratory, Boerne, TX) according to manufacturer’s instructions. Cows were classified as hypocalcemic when the concentration of calcium from the blood sample was ≤8 mg/dL (Reinhardt et al., 2011).

3.3.4. Monitoring Cow Behavioral Activity

Electronic data loggers (IceQube™, IceRobotics, Edinburgh, Scotland, UK) were placed on the hind leg of periparturient dairy cows at 7 ± 3 d prior to the expected calving date and removed at 14 ± 3 DIM. At milking time, data loggers were removed from cows and data from individual lactating dairy cows were exported from IceRobotic software into an Excel spreadsheet (Microsoft Corp., Redmond, WA). Activity data such as number of steps (n/d), standing time (min/d), number of lying bouts (LB; n/d), and mean duration of LB (min/b) were recorded from each individual cow.

3.3.5. Statistical Analyses

Data from individual lactating dairy cows (e.g., parity, sex of calf, twins, and stillbirth) were exported from DairyComp 305 into an Excel spreadsheet (Microsoft Corp., Redmond, WA; Table 1). Distribution of assisted and unassisted Holstein dairy cows with respect to lactation number, BCS immediately after calving, sex of calf, twins,
and hypocalcemia status were analyzed using MIXED procedure of SAS (Table 1; SAS, 2009). The proportion of stillbirth was analyzed using the GLIMMIX procedures of SAS (Table 1; SAS, 2009).

Activity data such as number of steps (n/d), standing time (min/d), number of LB (n/d), and mean duration of LB (min/b) were summarized daily (24 h period) for the analysis. The effect of parity (primiparous vs multiparous) and CE (assisted vs unassisted) on cow activity patterns 4 d prior to parturition were analyzed using MIXED procedures of SAS (Figures 1-2; SAS, 2009). The activity patterns by parity (Figure 1) and CE (Figure 2) on d -1, -2 and -3 were compared with d -4 (baseline). Additionally, the activity patterns between parities (Figure 1) and CE (Figure 2) were compared within each day. Data from unassisted cows (primiparous and multiparous combined) were used to assess cow behavioral activity prior to parturition on d -1, -2 and -3 were compared with d -4 (baseline). A model procedure that included parity (primiparous or multiparous), CE (assisted or unassisted), calcium status, and BCS at calving was used to compare differences among group of cows. Non-significant variables were eliminated from the model one at a time using the Wald statistic backward selection criterion (P > 0.15). Herd was included as a random effect and day was included as a repeated measures. The differences in cow activity (steps, standing time, LB, and mean duration of LB) between least squares means were computed by including the PDIFF option in the LSMEANS statement (Bas et al., 2011). Differences in individual least squares means were adjusted by using the Tukey-Kramer method. Least squares means and standard
errors of the means (±SEM) were reported. A P < 0.05 was considered statistically significant.

3.4. Results

A total of 147 cows experiencing unassisted (n = 132; CE score of 1) and assisted (n = 15; CE scores of 2-3) births were included in the analyses (Table 1). The average lactation number, BCS, proportion of males, hypocalcemia status, and twin births were not different (P > 0.05; Table 1) between cows experiencing assisted and unassisted births. Cows experiencing assisted birth (dystocia) had greater proportion of stillbirth compared to unassisted cows (P < 0.05; Table 1).

3.4.1. Effect of parity on cow behavioral activity prior to calving

The mean number of steps and mean duration of LB was not different (P > 0.05) between primiparous and multiparous cows (Figure 1). Primiparous cows spent less time per day standing (P < 0.05) on d -4 (570), -3 (573), -2 (544), and -1 (452) than multiparous cows on d -4 ((740), -3 (715), -2 (699), and – 1 (600; Figure 1). Additionally, primiparous cows had fewer (P < 0.05) LB on d -2 (21.8) and -1 (12.9) prior to calving compared to multiparous cows on d -2 (27.9) and -1 (17.8; Figure 1).
3.4.2. Effect of parturition on cow behavioral activity prior to calving

Activity data from unassisted cows (n = 132; primiparous and multiparous combined) were used to assess cow behavior prior to parturition. The overall mean number of steps significantly increased (P < 0.05) 24 h (d -1; 2379) before calving compared to the mean number of steps on d -4 (1597), -3 (1714), and -2 (1697; Figure 2). Additionally, the mean standing time significantly decreased (P < 0.05) on d -1 (536) compared to d -4 (665), -3 (653), and -2 (631). The overall mean number of LB per day significantly increased (P < 0.05) on d -2 (24.8), and -1 (15.4) compared to d -4 (11.4) and -3 (10.3) while the overall mean duration of LB decreased (P < 0.05) on d -1 (37) compared to -4 (53.1), -3 (62.4), and -2 (57.6).

3.4.3. Effect of unassisted or assisted births on cow behavioral activity prior to calving

The mean standing times did not differ (P > 0.05) between unassisted and assisted cows (Figure 2). Cows experiencing assisted births had fewer steps on d -1 (1638) compared to unassisted cows (2376; Figure 2). Additionally, assisted cows had fewer LB on d -2 (20.1) and -1 (16.25) compared to unassisted cows on d -2 (25.5) and -1 (15.8), respectively (Figure 2). Cows experiencing assisted births had longer mean duration of LB on d -4 (95.7), -2 (92.7), and -1 (90.6) compared to unassisted cows on d -4 (53.1), -2 (57.6), and -1 (37; Figure 2).
3.5. Discussion

The objectives of this study were to assess the effect of parturition, parity, and dystocia on daily cow behavioral activity patterns (steps, LB, standing time, and duration of LB) prior to parturition. Through the use of electronic data loggers (Huzzey et. al., 2005; Ledgerwood et al., 2010; Aungier et al., 2012; Elischer et al., 2013), the study showed that (1) behavioral cow activity changed 24 h prior to parturition (increased number of steps and number of LB with decreased standing time and decreased duration of LB); (2) primiparous cows spent less time standing and had fewer LB prior to calving compared to multiparous cows; (3) cows with assisted births took fewer steps, had fewer LB, and had longer duration of LB prior to calving compared to unassisted cows.

Changes in cows’ behavior and activity patterns as parturition approaches, regardless of difficulty of delivery or parity, have been reported (Huzzey et al., 2005; Wehrend et al., 2006; Miedema et al., 2011ab; Barrier et. al., 2012; Jensen et al., 2012). Parturition is divided into 3 stages (Noakes et al., 2001; USDA, 2010) characterized by hormonal, behavioral, and physical changes (e.g. dilation of soft tissues and cervix), and under normal conditions (eutocia) it progresses gradually from one stage to the next (Wehrend et al., 2006; Miedema et al., 2011a; Schuenemann et al., 2011) ending with the delivery of the calf (Noakes et al., 2001; Schuenemann et al., 2011). The present study, periparturient cows had increased number of LB with decreased duration of LB 24 h prior to parturition. Increased standing time (Huzzey et al., 2005) or LB (Miedema et al., 2011ab) has been previously reported in periparturient cows. This pattern of behavioral
activity has been described as a restless behavior such as increased frequency of postural changes (Barrier et al., 2012; Jensen et al., 2012) commonly observed prior to calving and has been attributed to discomfort during delivery (Huzzey et al., 2005; Schuenemann et al., 2011). Additionally, the increased number of steps and decreased standing time 24 h prior to parturition observed in the present study was also reported 12 h prior to calving elsewhere (Miedema et al., 2011ab). However, a significant increase in standing time during the active calving period compared with both pre- and post-calving periods has been reported (Huzzey et al., 2005). Huzzey et al. (2005) moved cows into individual maternity pens approximately 1 d before calving until 1 d after calving compared to the present study where cows were moved into individual maternity pens at the onset of calving and immediately moved into fresh pens after delivery. Perhaps the length of time in maternity pen and facility design might explain, at least in part, the observed differences between studies.

The effect of parity on cow behavioral activity as parturition approaches has been described elsewhere (Wehrend et al., 2006; Schuenemann et. al., 2011; Miedema et al., 2011a). In the present study, primiparous cows spent less time standing and had fewer LB prior to calving compared to multiparous cows. Variation in behavioral signs such as frequency of transitions from lying to standing (Schuenemann et al., 2011) and restlessness behavior (e.g., pawing, tail raising, and vocalization) have been reported between primiparous and multiparous cows (Wehrend et al., 2006; Miedema et al., 2011a). Perhaps primiparous cows may not have fully acquired their maternal experience...
and they are more prone to restless behavior due to pain prior to parturition (Wehrend et al., 2006). To the best of our knowledge, this is the first study to quantify differences between primiparous and multiparous using activity data loggers rather than observational techniques.

The effect of assisted birth on behavioral activity patterns prior to parturition has been described (Wehrend et al., 2006; Proudfoot et al., 2009; Miedema et al., 2011a; Schuenemann et al., 2011; Barrier et al, 2012). In the present study, calving difficulty was assessed using a 4-point scale (Lombard et al., 2007; Schuenemann et al., 2011). Although assisted and unassisted cows had more steps 24 h prior to parturition compared with d -2, -3 and -4, assisted cows (scores 2-3) took fewer steps 24 h prior to parturition compared to unassisted cows. Additionally, assisted and unassisted cows had more LB on d -1 and -2 prior to calving compared with d -3 and -4 with significantly fewer LB on d -2 for assisted cows. Although increased cumulative standing bouts (transition from standing to lying positions) have been reported for assisted compared to unassisted cows 24 h before calving (Proudfoot et al., 2009), another study reported no differences in transitions from lying to standing or the duration of LB using data captured by video (Barrier et al., 2012). In the present study, the duration of LB was shorter on d -1 compared with d -2, -3, and -4 for unassisted cows and no differences were observed for assisted cows during the 4 d prior to calving. When the duration of LB was assessed by day, it was significantly longer for assisted cows on d -1, -2, and -4 compared to unassisted cows. It is generally agreed upon that assisted cows show earlier and greater
restlessness behavior characterized by a variety of measures (Wehrend et al., 2006; Barrier et. al, 2012). Perhaps the altered behavioral activity observed in assisted cows could be associated with an earlier onset of labor and the subsequent associated pain (Barrier et al., 2012). Hypocalcemia at calving has been associated with dystocia (Curtis et al., 1983). Although no differences were observed in daily standing bouts between control and those cows with subclinical hypocalcaemia in the 7 d before calving (Jawor et al., 2012), cows with subclinical hypocalcemia stood longer during the 24 h period before parturition regardless of the difficulty at birth (Jawor et al., 2012); suggesting that these cows may be experience increased discomfort at calving. Calcium status at calving was not assessed in the present study; however, there was no difference in calcium status 7 d prior to parturition between assisted and unassisted cows.

These findings have important implications for dairy personnel executing calving tasks under field conditions. This study provided evidence that cows approaching parturition (regardless of parity or difficulty at birth) showed a distinct behavioral pattern (steps, standing time, and duration of LB) 24 h before calving. Furthermore, cows with assisted births had fewer steps and longer duration of LB with increased prevalence of stillbirth compared with unassisted birth. The observation of AS or feet appearance outside the vulva as well as calving progress are clear and concrete landmarks that calving personnel can easily identify. The potential benefits of electronic data loggers (precision management around the time of calving) as predictor of parturition or difficult births in real-time and around-the-clock would allow dairy producers and their personnel
to improve the overall herd performance (survival, health, and productivity) by reducing the prevalence of calving-related events such as stillbirth or mortality due to late interventions. Therefore, the use of electronic data loggers to predict behavioral changes of cows prior to parturition under different management conditions warrant further investigation.

3.6. Acknowledgements

The authors thank the collaborating dairy farms and their staff for providing the animals used in this study and their assistance during the project. This project was partially supported by the Ohio Dairy Producer Association, Epperson Summer Research Fellow, and Coba/Select Sires Inc.

3.7. References


3.8 Tables and Figures

Table 1. Distribution of assisted and unassisted Holstein dairy cows with respect to lactation number, BCS immediately after calving, sex of calf, twins, stillbirth, and hypocalcemia.

<table>
<thead>
<tr>
<th>Items</th>
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</tr>
</thead>
<tbody>
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<td></td>
<td>Unassisted (n = 132)</td>
<td>Assisted (n = 15)</td>
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<td></td>
</tr>
<tr>
<td>Lactation number (n)</td>
<td>2.6</td>
<td>2.3</td>
<td>0.75</td>
<td></td>
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<tr>
<td>BCS†</td>
<td>3.8</td>
<td>3.9</td>
<td>0.98</td>
<td></td>
</tr>
<tr>
<td>Male, %</td>
<td>51</td>
<td>60</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>Twins, %</td>
<td>1.5</td>
<td>0</td>
<td>0.98</td>
<td></td>
</tr>
<tr>
<td>Stillbirth‡, %</td>
<td>2.2</td>
<td>20</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Hypocalcemia (≤8 mg/dL)§, %</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

*Calving ease (unassisted or assisted births) of Holstein dairy cows were recorded at calving using a 4-point scale (Schuenemann et al., 2011).

†Body condition score (BCS) was assessed 7 ± 3 d prior to calving using a 5-point scoring system (Ferguson et al., 1994).

‡Stillbirth was defined as a calf born dead or died within 24 h after births from normal gestation length.

§The proportion (%) of cows with hypocalcemia (≤8 mg/dL) was assessed 7 ± 3 d before the expected calving using total serum calcium concentration (Reinhardt et al., 2011).
Figure 1. Mean number of steps (n/d), standing time (min/d), lying bouts (n/d), and duration of lying bouts (min/b) 4 d prior to calving in primiparous and multiparous Holstein dairy cows experiencing unassisted births. Primiparous (n = 33) and multiparous (n = 99) Holstein dairy cows were monitored for signs of imminent births prior to parturition. The effect of parity on daily number of steps (n/d), standing time (min/d), number of LB (n/d), and mean duration of LB (min/b) 4 d prior to calving were assessed (24 h period). The activity patterns on d -1, -2, and -3 of primiparous and multiparous cows were compared with d -4 (baseline; different letters within cow group differ significantly at P < 0.05). Additionally, the activity patterns on d -1, -2, and -3 between primiparous and multiparous cows were compared within day (solid lines with an asterisk on top indicate that both groups differ significantly at P < 0.05).
Figure 1.
Figure 2. Mean number of steps (n/d), standing time (min/d), lying bouts (n/d), and duration of lying bouts (min/b) 4 d prior to calving in Holstein dairy cows experiencing unassisted or assisted births. Holstein dairy cows (n = 147) were monitored for signs of births prior to parturition. The effect of assisted (n = 15) or unassisted births (n = 132) on number of steps (n/d), standing time (min/d), number of LB (n/d), and mean duration of LB (min/b) 4 d prior to calving were assessed and reported daily (24 h period). The activity patterns of assisted and unassisted cows were compared with d -4 (baseline; different letters within cow group differ significantly at P < 0.05). Additionally, the activity patterns between assisted and unassisted cows were compared within day (solid lines with an asterisk on top indicate that both groups differ significantly at P < 0.05).
Figure 2.
Chapter 4

Effect of metritis on daily activity patterns in lactating Holstein dairy cows

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4.1. Abstract

Metritis increases the risk for mortality and reduces milk yield and reproductive performance of lactating dairy cows. The objective of the present study was to assess the effect of metritis on activity behavior 4 d before and after diagnosis. A total of 15 lactating Holstein cows diagnosed with metritis were matched with 15 non-metritis lactating Holstein cows. All cows were housed in free-stall barns and calved during the same week. Electronic data loggers (IceQube™, IceRobotics, Edinburgh, Scotland, UK) were placed on the hind leg of periparturient dairy cows at approximately 7 ± 3 d prior to the expected calving date and remained until 14 ± 3 DIM. Metritis was defined as a fetid red-brown watery vaginal discharge with systemic signs of illness within 21 DIM. Calving ease (CE; scale 1-4) of cows, parity, and stillbirth (born dead or died within 24 h) were recorded. The number of steps (n/d), standing time (min/d), number of LB (n/d), and mean duration of LB (min/b) were recorded. Activity patterns of metritis cows were compared to non-metritis cows. Data were analyzed using MIXED procedures of SAS. Activity patterns for metritis or non-metritis cows were adjusted for the effect of herd, parity, and CE. Metritis cows spent more time standing, had fewer steps and LB, and LB of longer duration on 1-3 d prior to diagnosis compared to non-metritis cows (P < 0.05). These findings provided evidence that cows experiencing metritis showed distinct behavioral activity patterns 1-3 d prior to diagnosis. Although proactive management practices to prevention metritis should be a top priority for dairy herds, monitoring
transition cow activity may help identify those cows at risk of metritis before developing the clinical signs and improve the overall survival and welfare of metritis cows.

4.2. Introduction

Postpartum uterine diseases such as metritis (clinical or puerperal) are common disorders of lactating dairy cows that negatively affect survival, milk yield, and reproductive performance (LeBlanc et al., 2002a; Gilbert et al., 2005; Sheldon et al., 2006; de Vries et al., 2010), thus diminishing profitability of dairy herds (Overton and Fetrow, 2008). Metritis is defined as the inflammation of all layers of the uterus and is characterized by fetid red-brown uterine discharge with systemic signs of illness (i.e., fever and decreased milk yield and DMI) usually within 21 d postpartum (Sheldon et al., 2009; Dubuc et al., 2011a). Risk factors such as hygiene of the perineum at the time of calving (Schuenemann et al., 2011a), peripartum metabolic status (Földi et al., 2006; LeBlanc, 2008; Konyves et al., 2009), calcium balance at calving (Hunter et al., 2014), parity (Dubuc et al., 2010), retained fetal membranes (LeBlanc et al., 2002; Sheldon et al., 2009), delivery of twins (Földi et al., 2006), and dystocia (Földi et al., 2006) have all been associated with metritis in lactating dairy cows.

For most dairy operations, the diagnosis of metritis requires skilled veterinarians, well-trained personnel, attention to details, and time. Evaluating transition success only on the basis of clinical disorders substantially underestimates the opportunities for
superior transition management. Being able to provide care to cows in need of medical attention in a timely manner is important for survival (e.g., response to therapy and recovery), subsequent milk yield, and reproductive performance. The identification of sick animals such as those with metritis relies on the accurate observation of clinical signs and measurement of body temperature by transrectal thermometers (Sheldon et al., 2009; Dubuc et al., 2011). Although rectal body temperature is widely used to identify sick animals (especially during the transition period), it is influenced by many factors such as type of thermometer or the procedure itself (Burfeind et al., 2010), parity, month of calving, and type of disease diagnosed (Wenz et al., 2011). Monitoring cow activity may have a positive management (compliance) and economic impact by effectively identifying cows in need of medical attention under field conditions. For instance, lactating dairy cows experiencing metritis became depressed and consequentially less active; reducing feeding time (Huzzey et al., 2007) before the appearance of clinical signs compared to non-metritic cows. Monitoring the activity patterns of cows (in real-time and around-the-clock) within herd provide a clear opportunity to identify individual animals in need of medical attention. The technology to monitor cow-activity (e.g., Select Detect™, AfIMILK™) is available for reproductive programs in dairy cattle. Therefore, the objective of the present study was to assess the effect of metritis on activity behavior 4 d before and after diagnosis using electronic data loggers (IceQube™, IceRobotics, Edinburgh, Scotland, UK). The hypothesis was that lactating dairy cows experiencing metritis will exhibit distinct behavioral patterns compared to non-metritic cows.
4.3. Materials and Methods

4.3.1. Animals, Feeding, and Facilities

In total, 30 lactating Holstein cows from 1 dairy farms were used in the present study. Briefly, cows were housed in free-stall barns and milked thrice daily at approximately 8-h intervals. Cows were fed twice daily, in the morning and afternoon, with a TMR formulated to meet or exceed dietary nutritional requirements for lactating and dry dairy cows (NRC, 2001). This study was conducted from July 2011 through August 2012. The procedures described below were reviewed and approved by the Institutional Animal Care Use Committee, The Ohio State University.

4.3.2. Management of Dry Cows and Calving

Every week, a list of cows was obtained based on their calving dates using on-farm computer records (Dairy-Comp 305, Valley Agricultural Software, Tulare, CA). Pregnant cows were dried-off 60 ± 3 d before the expected calving date and moved into the dry pen immediately after the last milking. All cows were housed in similar close-up pens 21 d prior to the expected calving date and were moved into a contiguous individual maternity pen for parturition. Cows were closely monitored by on-farm personnel for signs of parturition (appearance of amniotic sac or feet of the calf outside the vulva) every 1 h (Schuenemann et al., 2011b; 2013). All calving personnel received the same training at the beginning of the study. The calving ease (CE) of cows (assistance provided at birth) were recorded using a 4-point scale (1 = no assistance provided; 2 = light
assistance by one person without the use of mechanical traction; 3 = mechanical extraction of the calf with an obstetric calf-puller; and 4 = severe dystocia: surgery or fetotomy needed; Schuenemann et al., 2011b). The perineum manure hygiene of cows (MHS) was scored using a 3-point scale (Schuenemann et al., 2011a) at calving to assess the presence of manure or dirt. Additionally, calving date and time, and stillbirth were recorded. Stillbirth was defined as a calf born dead or died (normal gestation length) within 24 h after birth (Schuenemann et al., 2011b).

4.3.3. Diagnosis of Metritis and Monitoring Cow Activity

Daily, a list of lactating cows at 7 ± 3 DIM was obtained from on-farm computer records (Dairy-Comp 305, Valley Agricultural Software, Tulare, CA) and screened for metritis. Metritis was defined as fetid watery red-brown vaginal discharge with systemic signs of illness such as fever (rectal temperature ≥39.5 °C) and decreased milk yield usually within 21 d postpartum (Sheeldon et al., 2009; Dubuc et al., 2011). Cows diagnosed with metritis (d 0; Figure 1) were then matched with a non-metritis cows that calved the same day and accounting for the effect of parity. Additionally, cows had their BCS (scale 1–5; Ferguson et al., 1994) recorded 7 ± 3 d prior to calving.

Electronic data loggers (IceQube™, IceRobotics, Edinburgh, Scotland, UK) were placed on the hind leg of periparturient dairy cows at 7 ± 3 d prior to the expected calving date and removed at 14 ± 3 DIM. At milking time, data loggers were removed from cows and data from individual lactating dairy cows were exported from IceRobotic software
into an Excel spreadsheet (Microsoft Corp., Redmond, WA). Activity data prior to- and after metritis diagnosis such as number of steps (n/d), standing time (min/d), number of lying bouts (LB; n/d), and mean duration of LB (min/b) were recorded.

4.3.4. Statistical Analyses

Data from individual lactating dairy cows (e.g., lactation number, milk yield, sex of calf, twins, and stillbirth) were exported from DairyComp 305 to an Excel spreadsheet (Microsoft Corp., Redmond, WA; Table 1). The distribution of cows with and without metritis with respect to lactation number, BCS, proportion of male, multiple births, stillbirth, MHS, milk yield (kg), and rectal body temperature were analyzed using MIXED procedure of SAS (Table 2; SAS, 2009).

Activity data such as number of steps (n/d), standing time (min/d), number of LB (n/d), and mean duration of LB (min/b) were summarized daily (24 h period) for the analysis. The effect of metritis on cow activity patterns 4 d prior to- and 4 d after diagnosis (d 0) of metritis were analyzed using MIXED procedures of SAS (Figure 3; SAS, 2009). The activity patterns for metritis and non-metritis cows were compared with d -4 as the baseline. Additionally, the activity patterns were compared within each day between metritis and non-metritis cows. A model procedure that included uterine health status (metritis or non-metritis), parity (primiparous or multiparous), CE (assisted or unassisted), BCS at calving, milk yield at the first DHIA test was used to compare differences among group of cows. Non-significant variables were eliminated from the
model one at a time using the Wald statistic backward selection criterion (P > 0.15). The differences in cow activity (steps, standing time, LB, and mean duration of LB) between least squares means were computed by including the PDIF option in the LSMEANS statement (Bas et al., 2011). Differences in individual least squares means were adjusted by using the Tukey-Kramer method. Least squares means and standard errors of the means (±SEM) were reported. A P < 0.05 was considered statistically significant.

4.4. Results

A total of 15 lactating dairy cows experiencing metritis (n = 15) and matching non-metritis cows (n = 15) were analyzed. The distribution of lactation, BCS, proportion of male calves, twin births, stillbirth, hygiene scores of the perineum did not differ between metritis and non-metritis cows (P > 0.05; Table 2). Cows diagnosed with metritis had significantly reduced milk yield and increased rectal temperature compared to non-metritis cows (P < 0.05; Table 2). The number of steps, standing time (min/d), number of LB (n/d), and mean duration of LB (min/b) were assessed for changes in daily activity between metritis (n = 15) and non-metritis (n = 15) cows (Figure 3). Individual cow activity data was analyzed in 24-h blocks beginning 4 d prior to clinical diagnosis of metritis (or matched day post calving in non-metritis cows; Figure 3) until 4 d post diagnosis.
4.4.1. *Effect of metritis on daily cow activity*

Cows diagnosed with metritis had significantly (P < 0.05) fewer steps (2880) beginning 1 day before (d -1) clinical diagnosis compared to their matched non-metritis cows (3905; Figure 3). This decrease in steps continued to be significant (P < 0.05) following the clinical diagnosis for metritis cows on d 0 (3106), 1 (3072), and 2 (2839) compared to non-metritis cows (4024, 3880, and 3750, respectively; Figure 3). Cows diagnosed with metritis spent more time (min/d) standing on d 0 (623.8), 1 (618.8), 2 (623.2), and 4 (630.4) than their matched non-metritis cows on d 1 (491.9), 2 (504.2), and 4 (526.4) after diagnosis (Figure 3). There were no significant differences (P > 0.05) in number of LB per day between metritis and non-metritis cows prior to- and after diagnosis (Figure 3). Cows with metritis had significantly longer LB duration (min/b; P < 0.05) on d -1 (72.4), 0 (74.3), 1 (73.6), 2 (75.5), and 4 (73.5) than their matched non-metritis cows on d -1 (52), 0 (55.5), 1 (49.5), 2 (54.2), and 4 (56.2; Figure 3). Additionally, cows diagnosed with metritis had longer LB duration (min/b; P < 0.05) starting on d -1 prior to diagnosis and continues until d 4 following diagnosis compared to d -4 (Figure 3).

4.5. *Discussion*

The objective of this study was to assess the effect of metritis on daily activity patterns prior to and following diagnosis of clinical metritis (number of steps, number of LB, standing time, and mean duration of LB). Through the use of electronic data loggers
(Huzzey et al., 2005; Ledgerwood et al., 2010; Aungier et al., 2012; Elischer et. al., 2013), the study showed that cows affected with metritis (1) took fewer steps prior to and following diagnosis; (2) stood for a longer duration per day starting the day of diagnosis; and (3) laid longer per laying bout compared to their non-metritis matched cows.

Studies assessing behavioral changes of cows prior to metritis diagnosis showed that cows with metritis spent less time feeding post-partum than control non-metritis cows (Urton et al., 2005; Huzzey et al., 2007). Huzzey et al. (2007) also observed that cows with metritis become depressed, which is followed by a decrease in activity. In the present study, cow activity patterns 4 d prior to and following the clinical diagnosis of metritis were assessed. Metritis was defined as the inflammation of all layers of the uterus and is characterized by fetid red-brown uterine discharge with systemic signs of illness (i.e., fever, decreased milk yield) usually within 21 d postpartum (Sheldon et al., 2006; Dubuc et al., 2011). The present study showed that cows diagnosed with metritis had reduced milk yield (Dematawewa and Berger, 1997) and fever compared to non-metritis cows. Additionally, metritic cows took fewer steps 24 h prior to diagnosis, stood for a longer duration per day (starting at the time of diagnosis), and had longer duration of LB per day as opposed to non-metritis matched cows. Furthermore, these behavioral changes continued for at least 48 h for all variables assessed and up to 4 d following diagnosis for standing time and duration of LB. This could be a display of general sickness behavior which includes lethargy and anorexia (Mottram, 1997; Fleischer et al., 2001; Dantzer and Kelley, 2007) with the subsequent drop in dry matter intake (Huzzey
et al., 2007) and milk yield after parturition (Dubuc et al., 2011). The activity patterns assessed in the present study are consistent with these behavioral changes. For instance, anorexia would lead to decreased trips to the feed bunk resulting in fewer steps while lethargy would lead to fewer steps, longer duration of LB and standing time. As with all inflammatory process, metritis triggers an inflammatory cascade of events which in turn signals the brain (Tizzard, 2009) to induce a physiologic response to restore health during illness (Hart, 1988; Dantzer and Kelley, 2007). This response manifests as sickness behavior (e.g., anorexia, lethargy) and fever, which are commonly recognized as clinical signs of metritis (Sheldon et al., 2009; Dubuc et al., 2011). Although pain is associated with an inflammatory process such as metritis, it is a complex phenomenon that involves many nerve cells, nerve chemicals, and different nerve cell receptors in order to continue the pain signal to the spinal cord and brain (Besson, 1997). Pain is responsible for stress and can lead to distress (Clark et al., 1997ab). The adaptive pattern of behavior in metritic cows (less active animals) 24 h prior to diagnosis could indicate a reaction or response to pain (Anderson and Muir, 2005) compared to non-metritis cows. Accelerometer devices can be used to assess an animal’s movements in two or three dimensions. In cattle, the devices are attached to an animal using leg bands and behaviors such as standing time, steps, and duration of LB can be monitored. The use of accelerometers proved to be a useful tool to assess pain behavior in castrated calves (White et al., 2008) and this technology has been recognized as a pain measurement technique in food-producing animals (FDA, 2008).
Under the field conditions described above, this study provided evidence that cows experiencing metritis showed a distinct behavioral pattern (steps and duration of LB) 24 h before the onset of clinical signs. The potential benefits of electronic data loggers as a diagnostic tool to assess these behavioral changes in real-time and around-the-clock would allow dairy producers and their veterinarians to improve the overall herd performance (health and productivity) by improving animal care and reducing the risk of culling or mortality (e.g., due to late or no interventions). The ability to predict cows at-risk of metritis, and other transition cow diseases, will aid in critical management decisions about animals in need of medical attention as well as generate behavioral-metrics over time for metritis prevention. Proactive management practices to prevent metritis should be a top priority for dairy herds. Therefore, the use of electronic data loggers to predict behavioral changes of cows prior to the onset of clinical signs of metritis under different management conditions warrant further investigation.

4.6. Acknowledgements

The authors thank the collaborating dairy farms and their staff for providing the animals used in this study and their assistance during the project. This project was partially supported by the Ohio Dairy Producer Association, Epperson Summer Research Fellow, and Coba/Select Sires Inc.
4.7. References


4.8 Tables and Figures

Table 2. Distribution of non-metritis and metritis Holstein dairy cows with respect to mean lactation number, milk yield, and RT, BCS immediately after calving, sex of calf, twins, MHS, and stillbirth.

<table>
<thead>
<tr>
<th>Items</th>
<th>Non-Metritis (n = 15)</th>
<th>Metritis (n = 15)</th>
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<tr>
<td>Lactation number (n)</td>
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<td>2.3</td>
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<tr>
<td>Milk yield(^a), kg/d</td>
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<td>22.3</td>
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<tr>
<td>RT(^b), °C</td>
<td>38.6</td>
<td>39.8</td>
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</tr>
<tr>
<td>BCS(^c)</td>
<td>3.15</td>
<td>3.16</td>
<td>0.87</td>
</tr>
<tr>
<td>Male, %</td>
<td>46.6</td>
<td>60</td>
<td>0.59</td>
</tr>
<tr>
<td>Twins, %</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Stillbirth(^d), %</td>
<td>0</td>
<td>6.6</td>
<td>0.98</td>
</tr>
<tr>
<td>MHS(^e)</td>
<td>1.4</td>
<td>1.6</td>
<td>0.31</td>
</tr>
</tbody>
</table>

\(^a\) Lactating cows were screened for metritis at 7 ± 3 DIM. Metritis was defined as fetid watery red-brown vaginal discharge with systemic signs of illness such as fever (rectal temperature ≥39.5 °C) and decreased milk yield usually within 21 d postpartum (Sheldon et al., 2009; Dubuc et al., 2011).

\(^b\) The effect of metritis on milk yield (kg/d) was assessed at the first DHI test after calving.

\(^c\) Rectal body temperature was assessed at the time of metritis diagnosis.

\(^d\) Body condition score (BCS) was assessed immediately after calving using a 5-point scoring system (Ferguson et al., 1994).

Continue
Stillbirth was defined as a calf born dead or died within 24 h after births from normal gestation length (Schuenemann et al., 2011b).

Hygiene of the perineum (presence of manure or dirt) was scored using a 3-point scale (Schuenemann et al., 2011a).
Figure 3. Mean number of steps (n/d), standing time (min/d), lying bouts (n/d), and duration of lying bouts (min/b) 4 days prior to- and 4 d after diagnosis of metritis in Holstein dairy cows. Lactating Holstein cows were screened for metritis at 7 ± 3 DIM. Metritis was defined as fetid watery red-brown vaginal discharge with systemic signs of illness such as fever (rectal temperature ≥39.5 °C) and decreased milk yield usually within 21 d postpartum (Sheldon et al., 2009; Dubuc et al., 2011). A total of 15 lactating dairy cows experiencing metritis (n = 15) were matched (by parity and same calving date) with non-metritis cows (n = 15) for analysis. The effect of metritis on number of steps (n/d), standing time (min/d), number of LB (n/d), and mean duration of LB (min/b) 4 d prior to- and 4 d after diagnosis (day 0) of metritis were reported daily (24 h period). The activity patterns for metritis and non-metritis cows were compared with d -4 (baseline; different letters within cow group differ significantly at P < 0.05). Additionally, the activity patterns between metritis and non-metritis cows were compared within day (solid lines with an asterisk on top indicate that both groups differ significantly at P < 0.05).
Figure 3.

- **Steps (n/d)**
  - Metritis (n=15) and Non-Metritis (n=15) compared over time relative to diagnosis.
  - Significant differences indicated by asterisks.

- **Standing (min/d)**
  - Similar significant differences indicated by asterisks.

- **LB (n/b)**
  - Similar significant differences indicated by asterisks.

- **LB Duration (min/b)**
  - Significant differences indicated by asterisks.

Legend:
- Metritis (n=15)
- Non-Metritis (n=15)
Chapter 5

Summary and Conclusions

The overall objectives of the present study were (1) to assess the effect of parturition and difficult births (dystocia) on cow behavioral activity beginning 4 d prior to calving and (2) to assess the effect of metritis on cow behavioral activity 4 d prior to- and after diagnosis.

The national animal health and monitoring system (USDA, 2010), reported that 18.6% of first-calf heifers and 10.8% of cows experience dystocia. Therefore, improving the outcome of dystocia is paramount to reduce calving-related losses and improve animal welfare in dairy herds. It is well documented that dystocia increases the prevalence of stillbirth (Mee, 2004; Lombard et al., 2007), calf mortality within 30 d postcalving (Mee, 2008; Lombard et al., 2007), the likelihood of trauma on the dam (i.e., paresis), uterine disorders (Sheldon et al., 2009), and decreased milk yield (Dematawewa and Berger, 1997). Furthermore, cows that experience dystocia are at an increased risk to develop metritis and other metabolic diseases (i.e., ketosis, DA). Prevention of disease at the herd level requires an ongoing and constant effort with effective coordination of the whole system (animals, environment, and personnel). Substantial knowledge exists to prevent many diseases or conditions; however, it must be translated into on-farm applications or practices to have a measurable effect at the herd level. Calving-related
losses (survival, health, and productivity) and welfare practices have become known challenges for the dairy industry worldwide; and management practices have been associated with these problems. As dairy operation continue to grow and become larger (Schuenemann and Shulaw, 2012), it is increasingly important to provide proper care and welfare of all animals within herds.

The first aim of the present study assessed the effect of parturition and difficult births on cow behavioral activity 4 d prior to- and after calving. This aim provided evidence that cows approaching parturition (regardless of parity or difficulty at birth) showed a distinct behavioral pattern (steps, standing time, and duration of LB) 24 h before calving. Furthermore, cows with assisted births had fewer steps and longer duration of LB with increased prevalence of stillbirth compared with unassisted birth. Recognizing early signs of parturition or dystocia prior to birth may help identify those cows most at-risk and pre-plan a triage as opposed to waiting for the usual signs of intervention.

The second aim of the present study assessed the effect of metritis on cow behavioral activity 4 d prior to diagnosis. The data suggests that cows experiencing metritis had unique behavioral activity patterns (steps and duration of LB) 24 h before manifestation of clinical signs (diagnosis). The ability to predict cows at-risk of metritis, and other transition cow diseases, will aid in critical management decisions about animals in need of medical attention as well as generate behavioral-metrics over time for metritis prevention.
In conclusion, findings from both aims have important implications for dairy personnel executing calving tasks or identifying of sick cows under field condition. Proactive management practices to prevention stillbirth and metritis should be a top priority for dairy herds. The potential benefits of electronic data loggers as predictor of calving-related events and health status of cows in real-time and around-the-clock would allow dairy producers and their personnel to improve the overall herd performance (survival, health, and productivity) due to late interventions. Results from both aims provide the basis for futures studies aimed at predicting parturition and transition cow diseases to reduce the prevalence of calving-related losses in dairy herds managed under confinement systems.

5.1. References


List of References


FDA. 2008. Pain measurement techniques for food-producing animals could lead to pain control


