Prevalence and Risk Factors for Dystocia in Dairy Cattle – With Emphasis on Confinement Systems

John Mee

Teagasc, Animal and Bioscience Research Department, Animal & Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland
Email: john.mee@teagasc.ie

Take Home Messages

- The economic costs of dystocia are four-times greater than the treatment costs alone.
- Confinement is associated with increased risk of dystocia, particularly in heifers.
- Dystocia rates tend to be lower in industries where selection indices have prioritised calving ease over many years.
- The primary cause of dystocia in heifers is relative calf oversize due to high calf birth weight and/or inadequate maternal pelvic size.
- In cows, the primary cause of dystocia is abnormal foetal position associated with sire, breed of sire, fetal gender and fetal mortality.
- At the national level, control of dystocia is dependent upon genetic selection programmes and producer education programmes.
- At the farm level, control of dystocia is dependent upon sire selection, heifer rearing and veterinary-led investigation of high dystocia herds.
- At the animal level, control of dystocia is dependent upon calving management and the adequacy of obstetrical assistance.

Introduction

In intensive management systems there is a danger that as producer focus changes from clinical through sub-clinical disease to suboptimal performance metrics, the pain, distress and injuries associated with dystocia in individual animals will receive less attention. There is evidence to suggest that this lack of attention to individual cows is already occurring with the 'lost in the herd' and 'loser cow' syndromes in intensive large dairy units. Garry (2004) went so far as to state that in the U.S. dairy industry the welfare aspect of dystocia has been almost ignored. This review addresses the impacts, current prevalence, recent temporal trends and associated risk factors for dystocia, with emphasis on confinement systems, from which 90% of the world's milk is produced.

Impacts of Dystocia

In order of descending financial importance, dystocia in confinement systems impacts production (41% of costs), fertility (34%) and cow and calf morbidity and mortality (25%), excluding costs associated with increased culling, veterinary costs and other management costs (Dematawewa and Berger (1997). Production losses are greatest in high yielding cows and in early lactation, possibly associated with reduced dry matter intake (Newby et al., 2010). Recent Canadian studies show that of peripartum problems, dystocia has the greatest effect on future cow fertility (Bonneville-Hebert, et al., 2011), through increased risk of retained placenta and metritis (Hossein-Zahed and Ardalan, 2011) in addition to the effects on cow culling (Sewalem et al., 2008) and on stillbirth (Mee, 2004). Dystocia also increases the likelihood of calf respiratory and digestive disorders and subsequent heifer milk yield (Eaglen et al., 2011, Lombard et al., 2007, Oltenacu et al., 1988). Cows which experience dystocia are more likely to experience dystocia at a subsequent calving (Mee et al., 2011). When the costs associated with the interrelated sequelae of dystocia are included, the total cost of dystocia is four-times greater than treatment costs alone (Oltenacu et al., 1988).

Confinement Systems and Dystocia

Dairy cow management systems vary internationally between pasture only (e.g. New Zealand), pasture and confinement (e.g. Ireland) and confinement only (e.g. North America), though obviously within countries there is a range of, and variation within, these management systems. Confinement systems vary in their set up but typical defining characteristics of a confinement system are animals housed all year round, typically in freestall barns, outdoor access only for loafing, non-seasonal calving, TMR feeding and high milk yield per cow. This describes total confinement or zero-grazing systems. The defining characteristics of pasture-based systems are grazing for the provision of forage for at least six months of the year with housing for the remainder and seasonal calving. In some countries national or organizational regulations may mandate calving facilities, e.g. in Sweden dedicated calving pens must be provided by law and under organic regulations cows must calve in an individual pen; not tied-up (Sundberg et al., 2010). Systems vary in the genotype of the animals, their diet, their environment and their management, all of which can impact the risk of dystocia. While public opinion in some countries may disagree with confinement only (Ellis et al., 2009), when cows are given the choice between a free-stall barn and pasture they make a mixed choice (Legrand et al., 2009).

Regarding the possible differences between management systems, health and welfare, including calving performance, tend to be better in pasture compared to a confinement system (Olmos et al., 2009a,b). Higher dystocia rates in dairy cows have been reported in tie stall housing (Bendixon et al., 1986) (though not in all studies; Ostojic-Andric et al., 2011), possibly due to inadequate exercise and mobility and psychological stress. Tie stalls were used as the main calving facility by 51% of producers in a recent Canadian study (Vasseur et al. 2008). Confinement in calving pens compared to a yard or pasture has been associated with increased dystocia in beef heifers (Dufty, 1981) and cows (McDermott et al., 1992), possibly due to the psychological stress of confinement. In addition, calving in confined facilities has been associated with increased beef calf morbidity (Sanderson and Dargatz, 2000). However, it is not just the management system but the management of the system which is also critical to calving success (Vasseur et al., 2010).

■ Current Prevalence of Dystocia

At the cow level, dystocia rates in dairy industries with confinement systems (e.g. USA, The Netherlands, Canada) with similar genotypes (Holstein-Friesian) tend to be high (>5%), (Table 1). Commenting on the high dystocia rates in U.S. dairy compared to beef herds, Garry (2004) stated that dairy animals are not rigorously selected for calving ease and management is not directed at reducing dystocia risk. In general, countries with functional selection indices which include dystocia, have a lower prevalence (e.g. Norway), though dairy cow breed, management and environment also play a substantial role in influencing national dystocia rate. Though dystocia rates may appear to be low internationally, calving assistance rates are high, varying between 10 (Heringstad et al., 2007) and over 50% (Hansen, et al., 2004). At the herd level, dystocia rates follow a positively skewed distribution with a substantial proportion of herds having a low prevalence and a small proportion of herds with a high prevalence. Thus in attempting to address the prevalence of dystocia within dairy herds, research, and investigation and control programmes should concentrate on quantitative risk factor assessments of the upper quartile of herds even where the cow-level industry average prevalence is normal.

Table 1. International prevalence of dystocia in dairy heifers and cows (2000-2011).

Country	Breed of dam	Heifers (%)	Heifers & cows (%)	Dystocia definition	Reference
Australia	Holstein-Friesian	9.5	4.1	Severe dystocia – observed, very difficult or surgical assistance	McClintock (2004)
Canada	Holstein-Friesian	NR [a]	6.9	Hard pull and surgery	Sewalem et al., (2008)
Denmark	Holstein-Friesian	8.7	NR [a]	Difficult calving with or without veterinary assistance	Hansen, et al., (2004)
Ireland	Holstein-Friesian	9.3	6.8	Considerable calving difficulty and veterinary assistance	Mee et al., (2011)
France	Holstein-Friesian & Normande	NR	6.6	Hard pull and surgical intervention	Fourichon et al., (2001)
New Zealand	Holstein-Friesian	6.5	3.8	Calving difficulty	Xu and Burton (2003)
Norway	Norwegian Red	2.7	1.1	Difficult calving	B. Heringstad et al., (2007)
Spain	Holstein-Friesian	3.1	2.5	Calving needed assistance and caesarean sections	Lopez de Maturana et al., (2006)
Sweden	Swedish Red and White	3.9	1.9 [b]	Difficult calving; unable to calve without assistance	Steinbock (2006)
The Netherlands	Holstein-Friesian	NR	7.8 [c]	Difficult and very difficult birth	Eaglen and Bijma (2009)
UK	Holstein-Friesian	6.9	2.0 [b]	Serious calving difficulty	Rumph and Faust (2006)
USA	Holstein-Friesian	22.6	13.7	Needed assistance, considerable force and extreme difficulty	Gevrekci et al., (2006)

[a] not recorded, [b] cows only, [c] second calvers only

▪ Temporal Trends in Dystocia

There are only a limited number of recent publications on phenotypic or genetic temporal trends in dystocia in dairy herds internationally. In the industries for which statistics are available, dystocia rates appear to have increased in Canada, Denmark, the USA, and UK and in Sweden (Fatehi et al., 2006, Hansen, et al., 2004, McGuirk et al., 1999, Steinbock, 2006) but temporal statistics are not available for many other countries.

▪ Types of Dystocia

Dystocia occurs when there is a failure in one or more of the three main components of calving; expulsive forces, birth canal adequacy and foetal size and position. While all types of dystocia may occur in both heifers and older cows, the predominant types and risk factors differ between these parity groups. In heifers the primary types of dystocia, in descending order of importance, are oversized calves, abnormal foetal position and failure of the vulva to dilate. In older cows, the primary types of dystocia are abnormal foetal position, oversized calves, multiple foetuses, uterine inertia, uterine torsion and failure of the cervix to dilate. The dystocia rate can be up to three times greater in heifers compared to older cows (Meyer, et al., 2001).

▪ Risk Factors For Dystocia

Oversized Calves

By far the most common type of dystocia in domesticated dairy cattle is oversized calves. In wild ungulates calf oversize is rare as it has been eliminated by natural selection and is essentially a consequence of domestication. The two primary determinants of calf oversize are, in order of importance, calf birth weight and maternal pelvic size with these two factors accounting for 50 and 5-10% of the phenotypic variance in dystocia, respectively, (Meijering, 1984). The odds of dystocia increase by 13%/kg increase in birth weight (Johanson and Berger, 2003). There is a curvi-linear (threshold) relationship between birth weight and dystocia dependent upon pelvic area, breed, parity and dystocia case definition. For Holstein cows this threshold lies between 42 and 45 kg, above which dystocia rate increases significantly (Menissier and Foulley, 1979).

Calf birth weight, the most important predictor of dystocia risk, is most influenced by gestation length, which in turn is most influenced by parity, foetal gender, sire, dam breed or strain, maternal nutrition and by climate during the last trimester. Both short (<265d) and long (>285d) gestation lengths are associated with increased risk of dystocia (Philipsson, 1976). Foetal growth rate averages 0.3-0.4 kg/day during the last month of gestation; Meijering (1984). The birth weight of male calves, singleton calves and calves from older cows are 9, 8 and 15% greater than those of female calves, twins and calves from heifers (Kertz et al., 1997). Mean calf birth weight is highest (45 kg) at third calving in Holsteins (McClintock, 2004). The majority of the increase in dystocia rate for male calves (Johanson and Berger, 2003) is attributable to higher body weight (1-3 kg). However, morphology also contributes to increased risk of dystocia. Berger et al., (1992) for example, found higher dystocia rates for males across all birth weight ranges.

Genotype can account for up to 60% of the variation in birth weight though the heritability of dystocia is low (2-10%) (McClintock, 2004, Steinbock, 2006). An increase in calf birth weight and associated increase in gestation length and dystocia and stillbirth risk has been, in part, attributed to 'Holsteinization' amongst Swedish (Steinbock, 2006), Danish (Hansen et al., 2004) and UK (McGuirk et al., 1999) Friesian cattle. Holsteinization may be defined as an increase in the proportion of Holstein genes of North American origin in a cattle population. However, there is little evidence that high yielding cows have increased risk of dystocia (Ingvartsen et al., 2003). Amongst dairy breeds, purebreeding with Holsteins is associated with increased risk of dystocia compared to crossbreeding with some other dairy breeds, as reported by Heins et al., (2006) for Brown Swiss and Scandinavian Red sires. Furthermore, for each 1% increase in inbreeding in US Holstein heifers, Adamec et al., (2006) found a 0.30- 0.42% increase in probability of dystocia.

Most published data on the adverse effects of under or over feeding on calf birth weight and dystocia originate from beef cattle studies (Freetly et al., 2000). Studies with dairy heifers and older cows have shown little effect of maternal nutrition during the last month of gestation on calf birth weight or dystocia (Sorge, 2005). Two-thirds of foetal birth weight is accrued during the last trimester of gestation. Severe nutritional restriction during the last trimester, to the extent that the dam loses body condition, leading to reduced placental and foetal weight and pelvic area, can result in dystocia and stillbirth due to uterine inertia and inadequate relaxation of the pelvic ligaments (Gearhart et al., 1990, Grunert, 1979). Overfeeding during the last trimester, to the point that dam body condition score is increased can result in foetal oversize and excess adipose deposition in the birth canal in heifers with consequent dystocia and stillbirth (Grunert, 1979). Excess or inadequate body condition in Holstein-Friesian heifers at calving is a significant risk factor for increased incidence of calving assistance and dystocia (Drew, 1986). Within the pre-calving body weight range 520-600 kg and body condition range 2.75-3.50, differences in dystocia rate were not reported by Carson et al., (2000) in first calving Holstein-Friesians. While risk of dystocia is greater in very young or very old heifers, between two and three years of age, age at first calving has no effect on risk of dystocia (Meijering, 1984). Underweight (<260 kg) Holstein-Friesian heifers at service are at significantly greater risk of dystocia and the risk of calving assistance and dystocia also tends to increase in overweight heifers (>360 kg at breeding) (Drew, 1986).

Cold weather (air and wind chill temperatures of approximately -5 and -10^{o}C, respectively) during the last trimester has been associated with increased dry matter intake, increased thyroid hormone concentration, increased blood and nutrient flow to the uterus and increased gestation length and reduced plasma oestradiol concentrations leading to increased birth weight and dystocia (Colburn et al., 1997, Johanson and Berger, 2003, McClintock, 2004).

Effective pelvic area and dystocia is most influenced by sire, parity, weight at insemination, age, weight and body condition at calving, and inbreeding. Maternal pelvic area accounts for between 5 and 10% of the variation in dystocia (Meijering 1984). Whilst the probability of dystocia is a function of both birth weight and pelvic area, once a threshold pelvic area is reached further increases in birth weight or pelvic area have negligible effect on risk of dystocia. Pelvic area at calving is more closely correlated with body weight and dystocia than pelvic area at service. However, even at calving effective pelvic area in heifers can increase by up to 15% due to increased mobility of the iliosacral joints, relaxation of the pelvic ligaments, abdominal straining and changes in posture (Meijering, 1984). Neither internal nor external pelvimetries are currently widely used to predict dystocia in dairy heifers due to the imprecision of measurement and overlap in pelvic area between eutocia and dystocia. In dairy industries it is considered better to select for a reduction in dystocia directly by reducing calf birth weight than by selecting for increased maternal pelvic area or by culling small heifers. There are no clear relationships between type traits and calving ease in Holsteins (Cue at al., 1990).

Foetal Malposition

Abnormal foetal position most commonly presents as posterior malpresentation, foreleg malposture, breech malpresentation or cranial malposture, in that order. Though foetal malposition occurs at a low prevalence (<5%) (Mee, 1991a), it is the most common cause of dystocia in older cows accounting for 20 to 40% of cases (Meijering, 1984). Malpresented calves have a two-times higher risk of dystocia and a five-time higher risk of stillbirth (Mee, 1991a). Abnormal foetal position is most influenced by multiple births which have a four-times higher risk (Mee, 1991b), particularly if unilateral. Risk factors for twin ovulations include previous twinning (five-time higher risk, Mee, 1991b), parity (three-time higher risk in older cows, Mee, 1991b), season, herd, and high dry matter intake and high milk production. Foetal malposition is influenced also by sire, breed of sire (Holland et al., 1993), gender (males have a two-times higher risk, Holland et al., 1993), parity (two-time higher risk in older cows, Holland et al., 1993) and foetal mortality. Abnormal foetal position has a low heritability, essentially zero, and repeatability (Holland et al., 1993).

Uterine Inertia

Uterine inertia, where the cervix is fully dilated but uterine contractions are too weak to expel the foetus, is associated with approximately 10% of all dairy cattle dystocia, primarily in older cows (Sloss and Dufty, 1980). However, fat mobilisation in overfat heifers can reduce magnesium availability and calcium mobilisation leading to uterine inertia and prolonged stage two of calving. Uterine inertia may be primary, as in hypocalcaemia, hypomagnesemia, old age, debility, lack of exercise and preterm calving and possibly hyposelenaemia or secondary, as in prolonged, malposition and twin calving.

Failure of the Vulva or Cervix to Dilate

Incomplete dilatation of the vulva is more common in heifers while incomplete dilatation of the cervix is more common in older cows. These conditions are associated with confinement and periparturient environmental stress, premature assistance, hormonal asynchrony and preterm calving. The increased risk of vulval non-dilation and dystocia in heifers calving in stalls compared to pens or paddocks has been attributed to parturient stress and adrenaline and cortisol release (Dufty, 1981). Moving heifers or cows during stage one of calving was associated with increased risk of both dystocia and stillbirth compared to movement during stage two of calving (Carrier et al., 2006). Assistance at calving before the cervix and vulva are fully dilated can result in dystocia due to vulval and cervical non-dilation. Assistance less than one hour after the foetal hooves appear results in increased risk of using a calf puller, duration of assistance, dystocia, downer cows and reduced perinatal vigour while delaying assistance for more than two hours increases calving duration and induces hyperlactataemia in the neonate without any additional benefits (Mee, 2004). Calving assistance rate can be reduced and calf viability increased by monitoring progress and by implementing the '*two feet-two hours*' rule-of-thumb whereby assistance is rendered if the foetal feet have been visible for two hours, particularly in heifers (Mee, 2004). The practice of offering feed only in the evening or at night tends to reduce nocturnal calvings but may result in an increased risk of dystocia due to more intensive calving supervision (Mee, 2006). Environmental disturbance at calving, caused by the continuous presence of an observer, confinement or overcrowded calving accommodation (Dufty, 1981) can lead to reduced uterine motility, cervical dilatation and abdominal contractions with resultant prolonged calving and dystocia. The full impacts of transition heifer and cow management on cervico-vulval non-dilation and subsequent dystocia may be underestimated in confinement dairy units.

Uterine Torsion

This condition is relatively uncommon (approximately 5% of dystocia, primarily in older cows) (Frazer et al., 1996) but appears to be increasing in prevalence (10%) in veterinary-assisted dystocia. The intermediate risk factors are excessive foetal movement during stage one of calving as the foetus adopts the birth posture, increased uterine instability at term and possibly a deeper abdomen in some dairy breeds. Ultimate risk factors include foetal oversize and gender, debility and insufficient exercise (Frazer et al., 1996).

■ Conclusions

At the national level, control of dystocia is dependent upon genetic selection programmes with adequate weighting for calving ease and producer education programmes. At the farm level, control of dystocia is dependent upon specific sire selection, heifer growth and calving management and veterinary-led investigation of high dystocia prevalence herds. At the animal level, control of dystocia is dependent upon calving management and the adequacy of obstetrical assistance. Future research should prioritise across breed genetic evaluations for calving ease, marker assisted selection for calving traits, the impacts of dairy crossbreeding on calving performance, development of a calving/dystocia 'alarm' and protocols for pain relief in cows at calving.

■ References

Adamec, V., Cassell, B.G., Smith, E.P. and Pearson, R.E. (2006) Effects of inbreeding in the dam on dystocia and stillbirths in US Holsteins. J. Dairy Sci. 89:307-314.

Bendixen, P., Vilson, B., Ekesbo, I. and Astrand, D. (1986) Disease frequencies in Swedish dairy cows. I. Dystocia. Prev. Vet. Med. 4:307-316.

Berger, P.J., Cubas, A.C., Koehler, K.J. and Healey, M.H. (1992) Factors affecting dystocia and early calf mortality in Angus cows and heifers. J. Anim. Sci. 70:1775-1786.

Bonneville-Hebert, A., Bouchard, E., Du Tremblay, D. And Lefebvre, R. (2011) Effect of reproductive disorders and parirt on repeat breeder status and culling of dairy cows in Quebec. Can. J. Vet. Res. 75:147-151.

Carrier, J., Godden, S., Fetrow, J., Stewart, S. and Rapnicki, P. (2006) Predictors of stillbirth for cows moved to calving pens when calving is imminent. J. Dairy Sci. 84:(Suppl. 1) 195.

Carson, A.F., Dawson, L.E.R. and Gordon, F.J. (2000) The effect of heifer rearing regime on body size and milk production during the first lactation. Proc. British Soc. Anim. Sci. p. 13.

Colburn, D.J., Deutscher, G.H., Nielsen, M.K. and Adams, D.C. (1997) Effects of sire, dam traits, calf traits, and environment on dystocia and subsequent reproduction of two-year-old heifers. J. Anim. Sci. 75:1452-1460.

Cue, R.I., Monardes, H.G. and Hayes, J.F. (1990) Relationships of calving ease with type traits. J. Dairy Sci. 73:3586-3590.

Dematawewa, C.M.B. and Berger, P.J. (1997) Effect of dystocia on yield, fertility, and cow losses and an economic evaluation of dystocia scores for Holsteins. J. Dairy Sci. 80:754-761.

Drew, B. (1986) Factors affecting calving rates and dystokia in Friesian dairy heifers, the results of a large scale field trial. Ir. Grassl. and Anim. Prod. J. 20:98-104.

Dufty, J.H. (1981) The influence of various degrees of confinement and supervision on the incidence of dystokia and stillbirths in Hereford heifers. New Zealand Vet. J. 29:44-48.

Eaglen, S. and Bijma, P. (2009) Genetic parameters of direct and maternal effects for calving ease in Dutch Holstein-Friesian cattle. J. Dairy Sci. 92:2229-2237.

Eaglen,, S., Coffey, M., Woolliams, J., Mrode, R. And Wall, E. (2011) Phenotypic effects of calving ease on the subsequent fertility and milk production of dam and calf in UK Holstein-Friesian heifers. J. Dairy Sci. 94: 5413-5423

Ellis, K., Billington, K., McNeill, B and McKeegan, D. (2009) Public opinion on UK milk marketing and dairy cow welfare. Anim. Welf. 18:267-282.

Fatehi, J., Jamrozik, J., and Schaeffer, L.R. (2006) Phenotypic and genetic trends in Canadian Holstein female reproductive traits. Abst. Book 8th World Congress Genetics Appl. to Liv. Prod., Brazil, Abst. 1-56, p 21.

Fourichon, C. Beaudeau, F., Bareille, N. and Seegers, H. (2001) Incidence of health disorders in dairy farming systems in western France. Liv. Prod. Sci. 68:157-170.

Frazer, G.S., Perkins, N.R. and Constable, P.D. (1996) Bovine uterine torsion: 164 hospital referral cases. Theriogenology 46:739-758.

Freetly, H.C., Ferrell, C.L. and Jenkins, T.G. (2000) Timing of realimentation of mature cows that were feed-restricted during pregnancy influences calf birth weights and growth rates. J Anim. Sci. 78:2790-2796.

Garry, F.B. (2004) An overview of animal welfare in the U.S. dairy industry. Bov. Pract. 38:1-22.

Gearhart, M., Curtis, C., Erb, H., Smith, R., Sniffen, C., Chase, L and Cooper, M. (1990) Relationship of changes in condition score to cow health in Holsteins. J Dairy Sci. 73:3132-3140

Gevrekci, Y., Chang, Y.M., Kizilkaya, K., Gianiola, D., Weigel, K.A. and Akbas, Y. (2006) Bayesian inference for calving ease and stillbirth in Holsteins using a bivariate threshold sire-maternal grandsire model. Abst. Book 8th World Congress on Genetics Appl. to Liv. Prod. Brazil, Abst. 1-26, p 11.

Grunert, E. (1979) Clinical aspects of the nutritional status of the dam and parturition. In: Calv. Prob. and Early Viability of the Calf. Current Topics in Vet. Med. and Anim. Sci. 4:468-477.

Hansen, M., Misztal, I., Lund, M.S., Pedersen, J. and Christensen, L.G. (2004) Undesired phenotypic and genetic trend for stillbirth in Danish Holsteins. J. Dairy Sci.87:147 7-1486.

Heins, B.J., Hansen, L.B. and Seykora, A.J. (2006) Calving difficulty and stillbirths of pure Holsteins versus Crossbreds of Holstein with Normande, Montbeliarde, and Scandinavian Red. J. Dairy Sci. 89:2805-2810.

Heringstad, B., Chang, Y.M., Svendson, M. and Gianola, D. (2007) Genetic analysis of calving difficulty and stillbirth in Norwegian Red cows. J. Dairy Sci. 90:3500-3507.

Holland, M.D., Speer, N.C., LeFever, D.G., Taylor, R.E., Field, T.G. and Odde, K.G. (1993) Factors contributing to dystocia due to foetal malpresentation in beef cattle. Theriogenology 39, 899-908.

Hossein-Zadeh, N., Ardalan, M. (2011) Cow-specific risk factors for retained placenta, metritis and clinical mastitis in Holstein cows. Vet. Res. Commun. 35:345-453.

Ingvartsen, K.L., Dewhurst, R.J. and Friggens, N.C. (2003) On the relationship between lactational performance and health: is it yield or metabolic imbalance that cause production diseases in dairy cattle? A position paper. Liv. Prod. Sci. 83:277-308.

Johanson, J.M. and Berger, P.J. (2003) Birth weight as a predictor of calving ease and perinatal mortality in Holstein cattle. J. Dairy Sci. 86:3745-3755.

Kertz, A.F., Reutzel, L.F., Barton, B.A. and Ely, R.L. (1997) Body weight, body condition score, and wither height of prepartum Holstein cows and birth weight and sex of calves by parity: a database and summary. J. Dairy Sci.80:525-529

Legrand, A., von Keyserlingk, M and weary, D. (2009) Preference and usage of pasture versus free-stall housing by lactating dairy cattle. J. Dairy Sci. 92:3651-3658.

Lombard, J.E., Garry, F.B., Tomlinson, S.M. and Garber, L.P. (2007) Impacts of dystocia on health and survival of dairy calves. J. Dairy Sci. 90:1751-1760.

Lopez de Maturana, E., Legarra, A. And Ugarte, E. (2006) Effects of calving ease on fertility in the Basque Holstein population using recursive models. Abst. Bk 8th World Congr on Genetics Appl. to Liv. Prod. Brazil, Abst. 1-23:10.

McClintock, S.E. (2004) A genetic evaluation of dystocia in Australian Holstein-Friesian cattle. PhD, Univ. Melbourne.

McDermott, J., Allen, O., Wayne Martin, S. and Alves, D. (1992) Patterns of stillbirth and dystocia in Ontario cow-calf herds. Can. J. Vet. Res. 56:47-55.

McGuirk, B., Going, I and Gilmour, A. (1999) The genetic evaluation of UK Holstein Friesian sires for calving ease and related traits. An. Sci. 68:413-422

Mee, J.F. (1991a) Bovine perinatal mortality and parturient problems in Irish dairy herds. PhD dissertation, Natl. Univ. of Ireland, p. 1-365.

Mee, J.F. (1991b) Factors affecting the spontaneous twinning rate and the effect of twinning on calving problems in nine Irish dairy herds. Ir. Vet. J. 44: 14-20.

Mee, J.F. (2004) Managing the dairy cow at calving time. Vet. Clin. of North America Fd. Anim. Pract. 20:521-546

Mee, J.F. (2006) Est-il possible de limiter les velages de nuit? Le Point Veterinaire 266, 10-11.

Mee. J.F., Berry, D. and Cromie, A. (2011) Risk factors for calving assistance and dystocia in pasture-based Holstein-Friesian heifers and cows in Ireland. The Vet. J. 187:189-194.

Meijering, A. (1984) Dystocia and stillbirth in cattle – a review of causes, relations and implications. Liv. Prod. Sci.11:143-177.

Meyer, C.L., Berger, P.J., Koehler, K.J., Thompson, J.R. and Sattler, C.G. (2001) Phenotypic trends in incidence of stillbirth for Holsteins in the United States. J. Dairy Sci. 84:515-523.

Newby, N., Pearl, D., LeBlanc, S,. Leslie, K., von Keyserlingk, A and Duffield, T. (2010) Impact of dystocic calvings and retained placenta in dairy cattle on dry matter intake, milk production and serum acute phase proteins. Proc. 26th World Buiatrics Congress, Santiago, Chile, p.323.

Olmos, G., Boyle, L., Hanlon, A., Patton, J., Murphy, J. and Mee, J.F. (2009) Hoof disorders, locomotion ability and lying times of cubicle-housed compared to pasture-based dairy cows. Liv. Sci. 125:199-207.

Olmos, G., Mee, J.F., Hanlon, A, Patton, J., Murphy, J. and Boyle, L. (2009) Peripartum health and welfare of Holstein-Friesian cows in a confinement-TMR system compared to a pasture-based system. Anim. Welf. 18:467-476.

Oltenacu, P.A., Frick, A. and Lindhe, B. (1988) Use of statistical modeling and decision analysis to estimate financial losses due to dystocia and other disease in Swedish cattle. Proc. 5th Intl. Symp. Vet. Epidem. and Econ., Copenhagen, Denmark, 353-355.

Ostojic-Andric, D., Hristov, S., Novakovic, Z., Pantelic, V., Petrovic, M., Zlatanovic, Z. and Niksic, D. (2011) Dairy cow welfare quality in loose vs tie housing systems. Biotech. In Anim, Husb. 27:975-984.

Philipsson, J. (1976) Studies on calving difficulty, stillbirth and associated factors in Swedish cattle breeds III Genetic parameters. Acta Agri. Scand. 26:211-220.

Rumph, J.M. and Faust, M.A. (2006) Genetic analysis of calving ease in Holsteins in the U.K. based on data from heifers and cows. Abst. Book 8th World Congress on Genetics Appl. to Liv. Prod., Brazil, Abst. 1-25, p 11.

Sanderson, M. and Dargatz, D. (2000) Risk factors for high level calf morbidity risk from birth to weaning in beef herds in the USA. Prev Vet. Med. 44:97-106.

Sewalem, A., Miglior, F., Kistemaker, G., Sullivan, P. and Van Doormaal, B. (2008) Relationship between reproduction traits and functional longevity in Canadian dairy cattle. J. Dairy Sci. 91:1660-1668.

Sloss, V. and Dufty, J.H. (1980) Dystocia. Handbook of Bovine Obstetrics. Williams and Wilkins, Baltimore/London, 98-127.

Sorge, U. (2005) The effect of varied duration of the close up period of primiparous cows on the incidence of dystocia and perinatal calf mortality. PhD Diss, FU Berlin, Germany, 110 pp.

Steinbock, L. (2006) Comparative analysis on genetics of stillbirth and calving difficulty in Swedish dairy cattle breeds. Licentiate thesis, Swedish Univ. Ag. Sci., Uppsala, 22 pp.

Sundberg, T., Rydhmer, L., Fikse, W., Berglund, B. and Strandberg, E. (2010) Genotype by environment interaction of Swedish dairy cows in organic and conventional production systems. Acta Agric. Scand. Sect. A, 60:65-73.

Vasseur, E., Rushen, J., de Passille, A., Lefebvre, D. and Pellerin, D. (2010) An advisory tool to improve management practices affecting calf and heifer welfare on dairy farms. J. Dairy Sci. 93:4414-4426.

Vasseur, E., Rushen, J., Pellerin, D., Lefebvre, D. and de Passille, A. (2008) Development of an intervention strategy to improve welfare of replacement animals in Canadian dairy farms. Proc. WAFL, Ghent, Belgium, p.122.

Xu, Z.Z. and Burton, L. (2003) Calving difficulty. Reproductive performance of dairy cows in New Zealand. Final report monitoring fertility project. Liv. Improv. Corp.. p 1-51.