Genetics of stillbirth in dairy calves

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ABSTRACT

The aim of this study was to investigate factors affecting, and estimate variance components of, stillbirth using data collected as part of Livestock Improvement's Sire Proving Scheme. Only calves that reached full-term of gestation were considered (i.e. abortions and inductions were excluded). After editing there were 773,904 records on calf-fate collected from 1987 to 2004. The mean incidence of stillbirth was 7.2%. The fixed effect model fitted to the data included the effects of contemporary group, birth assistance code, the sex of the calf, the gestation length of the dam, whether the dam was primiparous or multiparous and mating type e.g. a Jersey cow mated to a Holstein-Friesian sire etc. Breed proportions of New Zealand (NZHF) and North American (OSHF) origin Holstein-Friesian and Jersey were also fitted in addition to the proportion of heterosis expected in the calf. Data were analysed by considering stillbirth as a binomial trait using the logit transformation in ASReml that included a sire-maternal-grandsire pedigree. The direct heritability of stillbirth was estimated to be 0.010 (s.e. 0.009). It was not possible to estimate the maternal heritability using this dataset. Estimates of fixed effects were obtained from ASReml by analysing stillbirth as a continuous trait, as back-transformed fixed effect estimates obtained using a binomial model are unreliable when the incidence is small. The largest effect on the probability of stillbirth was calving difficulty. Compared to no assistance at calving, the two categories of greatest calving difficulty resulted in 22% and 41% mortality. The next largest effect on stillbirth was gestation length, with longer gestations being associated with more stillbirths. Males were 1% more likely to be stillborn than females. OSHF were most likely to be stillborn, followed by Jerseys and then NZHF. Heterosis effects were significant and favourable, except between the two strains of Holstein-Friesians where there was no significant heterosis. The largest heterosis estimate was between NZHF and Jerseys. Unlike some overseas programmes, genetically selecting for reduced stillbirths would not be effective in New Zealand, crossbreeding and devising strategies to manage calving assistance and gestation length appear to be more worthwhile.

Keywords: stillbirth, threshold model, genetic parameter

INTRODUCTION

Stillbirths are defined as a calf that dies at or within 24 to 48 hours of parturition (Philipsson *et al.,* 1979). Stillbirth in dairy cattle reduces the number of replacements available and calves for sale and has obvious animal welfare implications. In extreme cases (and in association with dystocia) it is possible for both the cow and calf to die at parturition.

Studies from Sweden and Denmark have noted an increase in the proportion of calvings that result in stillborn calves in recent years (Steinbock *et al.,* 2003; Hansen *et al.,* 2004). In both studies the increased use of North-American Holstein genetics has been implicated as a possible reason for this trend somewhat supported by the fact that the incidence of stillbirth in first calver cows has risen from 9.5% in 1985 to 13.2% in 1996 in USA Holsteins (Meyer *et al.,* 2001).

In some studies stillbirth has been found to be a heritable trait (Luo *et al.,* 1999; Steinbock *et al.,* 2003; Hansen *et al.,* 2004). Heritabilities estimated on the linear scale, such as by Luo *et al.* (1999) are difficult to compare, as they need to be transformed to the underlying scale (Dempster and Lerner, 1950). However, transformation has been shown to give biased results when the incidence is low (Van Vleck, 1972). It is therefore statistically desirable to analyse stillbirth data with a model that accounts for the categorical nature of the data, such as a threshold model. Heritabilities estimated using threshold models using Danish and Swedish data were 0.12 to 0.13 (Steinbock *et al.,* 2003 and Hansen *et al.,* 2004).

The aim of this study was to estimate genetic parameters for stillbirth using a threshold model and to investigate factors affecting stillbirth.

MATERIALS AND METHODS

Data

The initial data set included records on 861,346 calvings from Livestock Improvement's Sire Proving Scheme. Data were excluded where calves were recorded as being of unknown sex and unknown fate, in addition to abortions, inductions and premature calvings. A summary of the fate categories is presented in Table 1. The data were also restricted to calves that were Holstein-Friesians (HF) and Jerseys (J) and their crosses. The edits led to the exclusion of 58,251 records.

TABLE 1: Calf fates recorded in the raw data.

Fate	Total Number	Female	Male	Unknown
Bobbied	300975	18415	280694	1866
Died	61169	24307	32384	4478
Reared	375383	351779	23410	194
Sold	85883	4996	80681	206
Unknown	37936	936	10455	26545
Total	**861346**	**400433**	**427624**	**33289**

Contemporary groups (CG) were defined as the birth location of the calf within a calving season. Data where the incidence of stillbirth was either all 1 or 0 within a CG were also removed (as this is a requirement for binomial models). There were 27,009 records excluded through this edit. The final data set included 773,904 records.

Data on gestation length, birth assistance code and parity of the dam were obtained from Livestock Improvement's database. Birth assistance codes (calving difficulty scores) were available and had four levels: 0 was where birth assistance was not reported, 1 was reported to be no assistance, 2 was minor assistance given and 3 was major assistance. The incidence of twinning was low (1.67%) and was not large enough to include in the model for estimation purposes. Gestation length was calculated as the difference, in days, between calving date and mating date of the calf's dam. The mating date was determined by calculating the expected mating date as calving date minus an assumed gestation length of 282 days and examining the actual recorded mating dates within an 11 day bracket of the expected mating date. The mating date (and hence sire) was assigned to a calving if there was only 1 mating date within the 11-day bracket. Mating type was fitted to investigate whether the probability of stillbirth was affected by parental breed combination, for example mating larger sire breeds to smaller cow breeds may be hypothesised to affect stillbirth adversely.

Some of the HF sires were known carriers of complex vertebral malformation (CVM). A subset of the data were analysed to investigate whether an association between stillbirth and CVM carrier status of the sire could be determined. The sires included in this analysis were HF and were required to be tested for CVM carrier status. This dataset included 52,798 records.

Statistical model

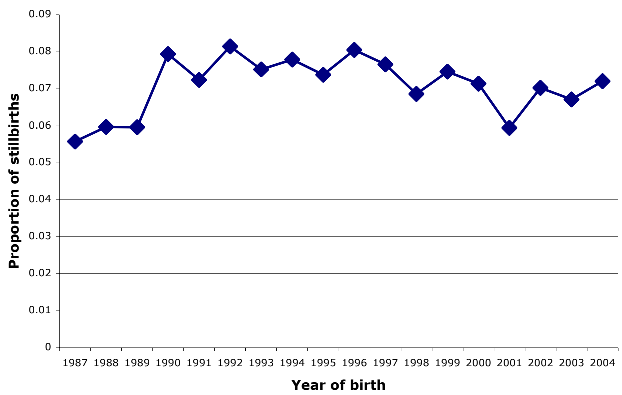
The fixed effect model fitted to the data included the effects of contemporary group, birth assistance code, the sex of the calf, the gestation length of the dam, whether the dam was primiparous or multiparous and mating type e.g. a Jersey cow mated to a Holstein-Friesian sire etc. Breed proportions of NZHF, OSHF and Jersey were also fitted in addition to the proportion of heterosis expected in the calf.

Data were analysed by considering stillbirth as a binomial trait using the logit transformation in ASReml (Gilmour *et al.,* 2002) that included a sire-maternal-grandsire pedigree. In the initial data set, 113 sires had less than 20 daughters and were excluded. The final pedigree included 4,401 sires of which 365 had daughters in the data.

RESULTS

The incidence of stillbirth in the final data set was 7.2%; in first parity dams the incidence was 7.4%, in older cows it was 7.1%. The phenotypic trend of stillbirth (Figure 1) shows that the incidence of stillbirth increased from 1987 to 1990, which could have been a data quality issue, rather than a true lower incidence of stillbirth. From 1990 to 2004, the trend has been relatively constant, with a small decrease in the number of stillbirths reported as time progresses.

FIGURE 1: The proportion of stillbirths (from full-term calves, excluding inductions) occurring in dairy cows participating in Livestock Improvement's Sire Proving Scheme



The heritability of stillbirth using a linear model was 0.002; transformed to the underlying scale using the formula of Dempster and Lerner (1950), the heritability is 0.0043. When the heritability is estimated directly on the underlying scale by analysing the trait as binomial, the heritability of stillbirth, for dams of all ages, was 0.010 (s.e. 0.009). In first parity dams, the heritability was similar (0.013).

Fixed effects estimated on the underlying scale need to be converted to the binomial scale. However, the low incidence of stillbirth causes problems with conversion. Even though analysing stillbirth as a continuous trait is not ideal statistically, it should provide robust enough approximations. The probability of stillbirth was highest in the two categories of greatest calving difficulty (Table 2; 22% and 41% more stillbirths than the mean, respectively).

Gestation length had an effect on stillbirth, with longer gestation length corresponding to increased mortality. Decreasing gestation length by one day is expected to result in a 0.17% decrease in calf mortality. Females are 1% more likely to survive than males at birth. Mating types had a significant effect on mortality with most stillbirth being in a Jersey breed cross.

TABLE 2: Least squares means deviations for the fixed effects of parity of dam, calving difficulty, gestation length, sex of calf and type of mating on stillbirth of calves.

Effect	Level	Estimate	s.e.
Parity of dam	1	0.0037	0.0008
	>=2	0.0	0.0
Calving difficulty	Not reported	0.0	0.0
	Reported no assistance	-0.0005	0.002
	Minor assistance	0.22	0.002
	Major assistance	0.41	0.005
Gestation length	Per day	0.0017	0.0006
Sex	Female	0	0
	Male	0.0098	0.0006
Type of mating	Other	-0.0083	0.002
	HF-HF	-0.0076	0.0031
	HF(male)-Jersey(female)	-0.0089	0.0027
	Jersey(male)-HF(female)	0	0
	Jersey-Jersey	0.0053	0.0027

Significant unfavourable effects of OSHF and Jerseys on stillbirth were found (Table 3), NZHF were least likely to have stillbirths. Crosses between both HF strains and Jerseys demonstrated similar amounts of heterosis.

TABLE 3: Breed and heterosis effects for stillbirth

Breed	Breed or heterosis	s.e.
NZHF	0.010	0.008
OSHF	0.036	0.008
J	0.019	0.008
NZHFxJ	-0.011	0.003
OSHFxJ	-0.010	0.003
OSHFxNZHF	-0.002	0.002

There was no detectable effect of CVM status of the sire on the probability of stillbirth of the calf.

DISCUSSION

The estimated heritabilities of stillbirth were low, but similar to the estimate of Luo *et al.* (1999) of 0.016 and smaller than the estimates obtained by McGuirk *et al.* (1999) of 0.08, Hansen *et al.* (2004) of 0.13 and Steinbock *et al.* (2003) of 0.12 (first parity dams). Luo *et al.* (1999), Hansen *et al.* (2004) and Steinbock *et al.* (2003) were able to estimate the maternal heritability in addition to the direct heritability. In these studies the maternal heritability was slightly larger than the direct estimate of stillbirth, indicating that stillbirth as a trait of the dam had a larger heritability than as a trait of the calf. In an attempt to estimate the maternal heritability in the present study, a model that accounted for the correlated additive genetic effects of sires and maternal grandsires was fitted. However, estimating the direct and maternal genetic covariance simultaneously was not feasible with these data, as the direct and maternal genetic covariance was larger than the direct and maternal variances.

The transformation of heritabilities estimated using linear models to the liability scale accounts for the incidence of a trait (Dempster and Lerner, 1950). Discrepancies between the heritability estimated when analysing stillbirth as a continuous versus binomial trait arise because the incidence of stillbirth is small and the adjustment to the underlying scale only really holds when the incidence is between 25% and 75% (Van Vleck, 1972). Inference of heritabilities on the liability scale should be from a model that accounts for the categorical nature of the data. However, correlations between sire breeding values estimated with linear and threshold models were high (0.9978). McGuirk *et al.* (1999) remarked that while threshold models may be useful in more unbalanced datasets with widely different incidences across fixed effects (e.g. contemporary groups) but may only offer small advantages in well-designed progeny testing programmes with large numbers of records per sire.

The heritability of stillbirth estimated using a threshold model was slightly larger where dams were in their first parity than dams in of all ages (0.013 versus 0.010); Steinbock *et al.* (2003) found a much larger difference in the direct heritability of stillbirth of 0.12 versus 0.02. They recommended that the genetic variation in stillbirth when the dam was 1st parity was worthwhile to provide genetic evaluations for sires. In the present study the heritabilities of stillbirth are small. As the phenotypic trend of stillbirth does not show a decline in the New Zealand population and the genetic variation is small, providing genetic evaluations for this trait in New Zealand is currently not warranted. Also, the genetic correlation between calving difficulty and stillbirth is moderate, 0.59 (Luo *et al.,* 1999) and 0.40 (McGuirk *et al.,* 1999) suggesting that selecting for easy calving sires will decrease the incidence of stillbirth as the major risk of stillbirth is due to disproportion between the size of the calf and the pelvis of the dam (Meijering*,* 1984). Calf size was not available for the present study; McGuirk *et al.* (1999) found evidence for an intermediate optimum (e.g. average sized calves were less likely to be stillborn).

Significant unfavourable effects of OSHF and Jerseys on stillbirth were found (Table 3), which supports the results from Steinbock *et al.* (2003) and Hansen *et al.* (2004) that North-American derived Holstein-Friesians (OSHF) had an effect on stillbirth. In both countries an increased trend in stillbirth has been observed corresponding to importation of Holstein genetics. In New Zealand the phenotypic trend for stillbirth does not appear to be increasing (Figure 1). One reason could be the relative increase in the number of crossbred animals in New Zealand. Favourable heterosis effects were observed in the cross between NZHF and Jerseys, followed by crosses between OSHF and Jerseys. The heterosis between NZHF and OSHF was not significant. The reason for more heterosis between NZHF and Jerseys than OSHF and Jerseys could have been because of the superiority of the NZHF in this trait with Jerseys and OSHF being more similar for this trait.

Selection for a reduction in calving difficulty and shorter gestation lengths would reduce the incidence of stillbirth. Gestation length has a heritability of 0.44 and Livestock Improvement already provide genetic evaluations for this trait (Winkelman and Spelman, 2001). The breed combination of sire and dam also had an effect on number of stillbirths, which is likely to be because of calving difficulty. The mating combination with the highest proportion of stillbirths was where sire and dam were both Jerseys. Interestingly, mating a Holstein-Friesian sire to a Jersey dam did not cause an increase in stillbirths; however this mating type was avoided in 1st parity SPS cows, with only 2,254 matings being of this type.

There was no detectable relationship between the CVM status of the sire, determined as being a carrier of an autosomal inherited recessive gene and the probability of stillbirth of the calf. Nielsen *et al.* (2003) showed that 77% of CVM homozygous foetuses are aborted before 260 days of gestation. As abortions and pregnancies that did not reach term were deliberately excluded from these data, it is perhaps not surprising that this effect was not found to be significant.

Unlike some overseas programmes, genetically selecting for reduced stillbirths would not be effective in New Zealand. Crossbreeding and devising strategies to manage calving assistance and gestation length appear to be more worthwhile.

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