Alternatives for Modelling of Traits within the Calving Traits Complex

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Abstract

Difficult calvings and losses of calf at birth are important factors for the welfare of the cow and the calf and also have severe economic consequences. For a long time in dairy cattle breeding, both characteristics have been regarded as separate although correlated traits. Scoring of calving ease bears the intrinsic problem of leading to a highly skewed distribution of observations across score classes. Stillbirth traditionally is considered as a well-defined trait. While this is true for the outcome of a calving, physiologically stillbirth has very different reasons and thus is needed to be re-defined in a more precise way. In the present study, using data from 81,419 calvings, it is attempted to find a new approach with consideration to the problems mentioned. Firstly, calving ease is considered as a binary trait since physiologically it makes more sense to differentiate the calvings as ‘normal’ or ’easy’ vs. ‘difficult’ or ’heavy’. Secondly, these two new alternative definitions of calving ease are matched with binary codes for stillbirth so that e.g. easy calvings resulting in a dead calf can be separated from heavy calvings also yielding a dead calf. Genetic parameters for a standard approach using a sire-mgs-model are compared with those for the newly defined traits. It can be shown that the magnitude and sign of the correlation between direct genetic and maternal genetic effects is depending on the definition of the respective trait. The approach is considered as useful for a supplementary analysis, especially when genomic data are jointly analysed in the form of a genome-wide association study.

Key words: dairy cattle, calving ease, stillbirth, reasons of stillbirth

Introduction

The relevance of the act of calving in dairy cattle husbandry and breeding is undisputed. Besides welfare aspects, effects of calving can have economic consequences due to loss of calf, death of dam, and extra labour cost directly associated with calving problems, including the need for veterinary assistance (Meijering, 1984). Furthermore, consequences of difficult calvings may lie in increased frequencies of reproductive disorders following calving and even increased culling rates for cows that had difficult calvings. In the general, two traits within the calving trait complex have been of special interest, calving ease (CE) and stillbirth (SB). Depending on the availability of suitable data, also gestation length and birth weights have frequently been subject to genetic and statistical analyses.

Scores for calving ease, commonly given by the dairy farmer, bear the intrinsic problem of showing a highly skewed distribution, i.e. easy calvings dominate while very difficult ones are rare. This finding gives reason for examining the use of alternative models for CE.

Besides environmental effects, CE and SB are influenced by direct genetic and maternal genetic effects which pertain to the genetic ability of the dam of giving birth to a calf and the genetic ability of the calf to be born. While a full agreement on this genetic background is obvious from the literature, a debate exists on the genetic covariance or correlation between direct genetic and maternal genetic effects. Numerous estimates exist in the literature, ranging from a strongly negative relationship to a positive one. Swalve et al. (2006), after having analysed a data set including the precise information on whether calvings were observed or not, hypothesized that the ‘true’ genetic correlation between direct and maternal effects would be masked by assistance given at calving which could be regarded as a kind of preferential treatment.

A more general question when considering calving traits and especially stillbirth is that physiologically very different reasons exist for the loss of a calf. Among all dead calves, being born still or dying shortly after birth, there will be very heavy ones but also very light ones. The heavy ones presumably have suffered from a very difficult birth while the light ones may not have been vital for very different reasons. Thus, the trait 'stillbirth' in reality is something composed of very different reasons and this fact should be taken into account, especially when trying to associate the phenotype stillborn with genomic data.

Aim of the present study was to contribute to the discussion on the aforementioned questions, i.e. the handling of the skewed distribution of CE, the magnitude and sign of the genetic correlation between direct and maternal genetic effects, and the different origins of stillbirths.

Materials and Methods

Data was collected in 21 large dairy farms with herd sizes between 200 and 2600 cows (average: 780 cows) which form the co-operator herd scheme of the cattle breeding organization Rinderzuchtverband Mecklenburg-Vorpommern in North-Eastern Germany. In these cooperator herds, data documentation for health traits and especially for the calving trait complex is supervised by personnel from the breeding organization and the State Research Institute of Mecklenburg-Vorpommern while for all other standard traits in dairy cattle breeding, e.g. production traits, conformation, reproductive performance, standard measures of recording are implemented. All calves from all calvings are weighed in these herds, be the calves alive or stillborn. Data collection spanned the period from October 2005 to April 2011. Edits were performed such that only Holstein cows with single births, with birth weights > 30 kg and with known sire of calf and sire of dam were included. The resulting data consisted of 81,419 calvings of which 30,589 calvings were from heifers.

Table 1. Coding of calving ease (CE1, CE2).

<table>
<tr><th></th><th>CE1</th><th>CE2</th></tr>
<tr><td>No information (0)</td><td>-</td><td>-</td></tr>
<tr><td>Easy (1)</td><td>0</td><td rowspan="2">0</td></tr>
<tr><td>Normal (2)</td><td rowspan="3">1</td></tr>
<tr><td>Heavy (3)</td><td rowspan="2">1</td></tr>
<tr><td>Operation (4)</td></tr>
</table>

Table 1 displays the coding of CE as it is standard practice in Germany and also other countries. Farmers are encouraged to use a score of 0 for unobserved calvings, however, usually this is actually done in rare cases only since farmers consider an unobserved but apparently easy calving as an easy calving and rather use the score of 1. Thus, for this study, calvings with a CE-score = 0 were not included in the data. 'Easy' calvings officially are defined as calvings without assistance while 'normal' denotes calvings with one person assisting and 'heavy' calvings are defined as more than one person assisting. Finally, a CE-score of 4 ('operation') is reserved for calvings under veterinary assistance consisting of either caesarean section or fetotomy.

The two right columns of Table 1 present alternative ways of defining CE in form of a binary trait. Re-defining a 'linear' trait in the form of a binary trait at first may seem unsuitable. However, for the special case of CE data, it is highly questionable if the 'linear' but highly skewed form of the trait is really an advantage. Furthermore, one argument could be that truly 'easy' calvings should be considered as a separate class while all other original values ranging from 2 to 4 may be highly dependent on randomly occurring conditions for a specific birth, e.g. the presence of one or two people assisting. Likewise, another argument could be that all easy calvings should be grouped together with one person assisting since on many farms it will be standard practice that one person is assisting and within farm it may again be a random occurrence whether no person or one person assisting is present. The above two arguments then lead to two alternative ways of defining binary CE with original codes as aggregated in Table 1.

For stillbirth, it is standard practice of recording the trait in a binary way and grouping together calf losses due to being born still or dying within 48 hours. This is shown in Table 2.

Table 2. Coding of stillbirth (SB).

	SB
Living calf	**0**
Born dead	**1**
Died within 48 hours	

Table 3 displays the frequencies (status = 1) resulting from binary coding of CE and SB. Using the CE1 definition, 44.1 % of all births from heifers show at least slight problems. From a purely statistical point of view, the CE1 coding thus has advantages, at least for heifers since the data is almost evenly distributed across both classes (0, 1). On the other hand, applying CE2 leads to a more uneven distribution of data but may be more justified from a biological point of view.

A threshold sire-mgs-model with a logit-link function and applied via ASReml3 (Gilmour *et al*., 2008) was used for genetic analysis. Herd-year-season of calving, the sex of the calf and age of first calving were considered as fixed effects for heifer calvings. For calvings from later parities and for a joint analysis of all calvings, parity number was included as a fixed effect. For calvings after parity three, parity = 3 was used.

Table 3. Frequencies (%) of births with problems (CE1 definition) and heavy births (CE2 definition), and stillbirth rate for entire data, heifer data, and cow data.

	All	Heifers	Cows
Births with problems (CE1 definition)	32.0	44.1	24.7
Heavy births (CE2 definition)	9.8	14.9	6.7
Stillbirths	5.4	8.7	3.4

Variance components for direct genetic, maternal genetic, and the covariance between both former components were derived as:

$$\begin{bmatrix} \sigma^2_D \\ \sigma_{DM} \\ \sigma^2_M \end{bmatrix} = \begin{bmatrix} 4 & 0 & 0 \\ -2 & 4 & 0 \\ 1 & -4 & 4 \end{bmatrix} \begin{bmatrix} \sigma^2_S \\ \sigma_{S,MGS} \\ \sigma^2_{MGS} \end{bmatrix}$$

Results & Discussion

Table 4 summarizes the results for estimates of direct and maternal heritabilities. In general, estimates were relatively high compared to literature values (e.g. Steinbock *et al*., 2003; Wiggans *et al*., 2003; van Pelt *et al*., 2009; Eaglen and Bijma, 2009). This finding most likely can be attributed to the limited number of large herds forming a relatively large data set and the thorough supervision of recording in the co-operator herds. Estimates for heifer calvings in general were larger than those for cow calvings. This pertains specifically to the estimate of a maternal genetic heritability of 0.28 for SB in heifer calvings but also to the direct genetic heritabilities and to a lesser extent to the corresponding heritabilities for CE1 and CE2. As expected, heritabilities for birth weight (BW) and gestation length (GL) were of substantial magnitude and thus would facilitate genetic selection for these traits if desired. However, as both traits clearly are traits for which an intermediate optimum is desired, the magnitude of these heritabilities should rather point to the fact that caution is needed when traits genetically related with BW and/or GL are subject to selection.

Despite the fact that the data set was of fairly large size, estimates for genetic correlations between direct and maternal effects had high standard errors. For heifer data, no estimate differed significantly from zero, the largest non-significant estimate for heifer data being equal to -0.235 for SB. For cow data, three significant genetic correlations between direct genetic and maternal genetic effects were found: 0.312 (SB), -0.293 (CE1), and -0.716 (CE2). This is somewhat in line with the study by van Pelt *et al*. (2009) who also did not find significant correlations for heifers but reported a correlation of -0.39 for CE, scored in six categories, in multiparous cows.

Table 4. Estimates of direct and maternal heritabilities from a REML threshold model analysis (for stillbirth rate, CE1, CE2) and a REML linear model (for birth weight, gestation length). Genetic effects fitted in form of a sire-maternal-grandsire model.

	Direct (First line: h^2, second line: s.e.)			Maternal (First line: h^2, second line: s.e.)		
	Heifers	Cows	All	Heifers	Cows	All
Stillbirth	0.138	0.074	0.104	0.281	0.032	0.180
(SB)	0.031	0.026	0.021	0.051	0.028	0.033
Easy - Assisted	0.141	0.102	0.111	0.101	0.069	0.087
(CE1)	0.020	0.014	0.012	0.019	0.016	0.013
Normal - Heavy	0.148	0.103	0.122	0.109	0.102	0.079
(CE2)	0.026	0.023	0.017	0.026	0.033	0.017
Birth weight	0.302	0.262	0.279	0.071	0.096	0.077
(BW)	0.025	0.024	0.016	0.013	0.015	0.010
Gestation length	0.443	0.419	0.439	0.066	0.091	0.086
(GL)	0.031	0.024	0.022	0.013	0.015	0.011

Except for the re-defining of CE as a binary trait, the above results originate from a ‘standard’ form of analysis for calving traits as has been carried out numerously before. From this ‘standard’ analysis, it already can be concluded that traits of the calving complex are heritable to an extent that genetic selection, especially for an improvement of heifer calvings, is promising, especially when the recording is accurate. Furthermore, a genetic antagonism between direct genetic and maternal genetic effects appears to exist and is visible in the form of stillbirths in heifer calvings and calving ease in cow calvings.

As stated in the introduction, a new approach for a joint analysis of SB and CE would be to form new traits such that SB can be separated for easy vs. assisted calvings (SB x CE1) or normal vs. heavy calvings (SB x CE2). Re-coding the data in this form yielded the frequencies as shown in Table 5.

Frequencies for the new trait combinations show that dead calves may be a result from ‘normal’ and even ‘easy’ calvings as well as from ‘heavy’ or ‘assisted’ calvings. It is not farfetched that this separation of SB biologically is more in line with the reasons for the loss of a calf.

Table 5. Distribution (relative frequencies in %) of data for new trait combinations of stillbirth rate and calving ease definition (CE1, CE2).

	EASY-ASSISTED (CE1)		NORMAL-HEAVY (CE2)	
	easy	assisted	normal	heavy
alive	54.3	36.2	80.3	11.1
dead	2.2	6.3	4.8	3.7

Table 6 presents estimates for direct genetic and maternal genetic heritabilities as well as the correlation between the two components for heifer calvings. In general, more pronounced results can be found for a combination of SB with CE2. Direct and maternal heritabilities for stillborn calves from ‘heavy’ births are of substantial and equal magnitude around 0.25. This finding most likely is reflecting the genetic background of prenatal growth. Another estimate of equal size is the maternal heritability for stillbirths which are not associated with difficult calvings. This could be a hint that effects of the dam leading to stillbirths do indeed exist which are independent of the size of the calf since the birth was coded as 'normal'. For living calves, are their births 'normal or 'heavy', heritabilities are substantially lower.

Unfortunately, all standard errors for the estimates of the genetic correlation between maternal genetic and direct genetic effects are relatively high. However, it is striking to see that the sign of the respective correlations changes across the different trait combinations.

Table 6. Estimates of direct and maternal heritabilities for combinations of two different binary definitions for calving ease (CE1, CE2) with stillbirth rate, and estimates for the genetic correlation of direct x maternal effects (first lines, second lines: s.e.).

SB x EASY-ASSISTED (CE1)

	Alive - Easy	Alive-Assisted	Dead-Easy	Dead-Assisted
h^2_{dir}	0.14 0.020	0.10 0.016	0.12 0.052	0.14 0.034
h^2_{mat}	0.12 0.021	0.05 0.014	0.11 0.069	0.26 0.055
$r_{g\ dir\ x\ mat}$	-0.02 0.128	0.05 0.168	0.32 0.525	-0.10 0.186

SB x NORMAL-HEAVY (CE2)

	Alive - Normal	Alive - Heavy	Dead - Normal	Dead - Heavy
h^2_{dir}	0.12 0.022	0.12 0.026	0.09 0.033	0.24 0.057
h^2_{mat}	0.15 0.027	0.06 0.023	0.25 0.060	0.25 0.072
$r_{g\ dir\ x\ mat}$	-0.12 0.146	-0.00 0.224	0.00 0.25	-0.32 0.189

Conclusion

Stillbirths are a mixture formed of calf losses containing light and heavy calves. From a joint analysis under combining SB and CE it shows the genetic correlation between direct genetic and maternal genetic effects depends heavily on the specific combination of SB and CE as well as on the definition of CE. Problems arising from births of large calves from very difficult births should be tackled via birth weight, i.e. birth weights should be recorded, monitored, and sires with extreme birth weights of their offspring should be excluded from the use in A.I. This is needed to keep birth weight at an intermediate optimum. Stillbirths not associated with the weight of the calf should be treated separately. Although the direct heritability in this case is lower, it is high enough to warrant genetic selection. Finally, difficult calvings although leading to a living calf, should also be subjected to genetic selection. The approach proposed could also be of interest in studies trying to identify associations with chromosomal regions with the aim of identifying genes of large effect. In this case it would be important to know whether significant associations merely point to genes with effects on the (prenatal) growth rate or two other genes possibly associated with e.g. vitality of the calf.

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