Relationships between Gestation Length, Calving Difficulty, and Perinatal Mortality in Primiparous Holstein Cows

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Abstract

Recursive structural equation models were used to explore biological relationships between gestation length (GL), calving difficulty (CD) and perinatal mortality (stillbirth (SB)) in cattle. An acyclic model was assumed, where recursive effects existed from the GL phenotype to the liabilities to CD and SB, and from the liability to CD to that of SB considering four periods regarding GL. The data contained GL, CD and SB records from 90,393 primiparous cows, sired by 1,122 bulls, distributed over 935 herd-calving year classes. The model indicated that GL slightly shorter than average would lead to the lowest incidence of CD and SB, and confirmed the existence of an intermediate optimum of GL with respect to these traits. In addition, estimated genetic correlations between direct effects for GL and CD and direct effects GL and SB varied as a function of the GL phenotype.

Introduction

Interest in birth-related traits has increased due to the economic value of calving traits and animal well-being considerations. Calving difficulty (CD) increases veterinary and labor costs, augments culling risk, increases mortality in cows and calves, decreases milk production in the next lactation, and impairs female fertility in the next reproductive cycle (DEMATAWEWA and BERGER 1997; LÓPEZ DE MATURANA *et al.* 2007a; LÓPEZ DE MATURANA *et al.* 2007b). Stillbirth (SB), defined as death prior to 24 or 48 hr after calving, also leads significant economic losses. A multifactorial non-infectious etiology of SB has been reported (MEYER *et al.* 2000; BERGLUND *et al.* 2003; STEINBOCK *et al.* 2003). Calving difficulty is a relevant predictor of SB, but more than half of stillborn calves are from normal or easy calvings (PHILIPSSON and STEINBOCK 2003; STEINBOCK *et al.* 2003). MEYER *et al.* (2000) found that gestation length (GL) was the third most important predictor of SB in primiparous and multiparous cows. These authors found nonlinear relationships between GL and SB, in agreement with other studies (MEIJERING 1986; HANSEN *et al.* 2004). Our objective was to explore relationships between calving traits using a recursive model, accounting for nonlinear relationships between GL phenotype and liabilities to CD and SB, as well as linear relationships between liabilities to CD and SB.

Data

The data included primiparous Holstein cows calving from 2000 to 2005 in the National Association of Animal Breeders (Columbia, MO) Calving Ease Program. All cows had records for GL, CD and SB. Gestation length was calculated as the interval between breeding and calving dates. Calving difficulty was scored on a 1 to 5 scale in which 1 corresponds to unassisted calvings, and 5 corresponds to extremely difficult calvings. Stillbirth was recorded as: 1 = alive, 2 = dead by 24 hr of age, and 3 = dead by 48 hr of age. Categories 4 and 5 for CD and 2 and 3 for SB were combined. The final data set contained GL, CD and SB records from 90,393 primiparous cows, sired by 1,122 bulls, mated to 567 service sires and distributed over 935 herd-calving year classes. A nonlinear relationship was observed between GL and the incidence rates of CD and SB, and there was an intermediate range of GL values (approximately 273 to 275 d) at which both CD and SB were lowest. Calves with shortest gestations had the highest rates of SB; the incidence of SB decreased as GL increased to

273 d, remained steady until GL reached 280 d, and increased thereafter. The incidence of CD was relatively constant for calves with GL from 266 to 275 d, but it increased steadily thereafter. Based on the non-linear phenotypic relationships observed between GL, CD, and SB, cows were grouped into 4 classes, such that a linear approximation could be used to describe the relationship between GL and the incidence rates of CD and SB within each group.

Methodology

A recursive Gaussian-threshold sire-maternal grandsire model was used. Models for GL, CD, and SB, respectively were as follows:

$$\mathbf{y}_{GL} = \mathbf{age}_{GL} + \mathbf{sex\_calf}_{GL} + \mathbf{season\_year}_{GL} + \mathbf{herd-year}_{GL} + \mathbf{sire}_{GL} + \mathbf{mgs}_{GL} + \mathbf{e}_{GL}$$

$$\mathbf{y}_{CD} = \lambda_{CD\leftarrow GL(k)}\mathbf{y}_{GL} + \mathbf{age}_{CD} + \mathbf{sex\_calf}_{CD} + \mathbf{season\_year}_{CD} + \mathbf{herd-year}_{GL} + \mathbf{sire}_{CD} + \mathbf{mgs}_{CD} + \mathbf{e}_{CD}$$

$$\mathbf{y}_{SB} = \lambda_{SB\leftarrow GL(k)}\mathbf{y}_{GL} + \lambda_{CD\leftarrow SB(k)}\mathbf{y}_{CD} + \mathbf{age}_{SB} + \mathbf{sex\_calf}_{SB} + \mathbf{season\_year}_{SB} + \mathbf{herd-year}_{GL} + \mathbf{sire}_{SB} + \mathbf{mgs}_{SB} + \mathbf{e}_{SB}$$

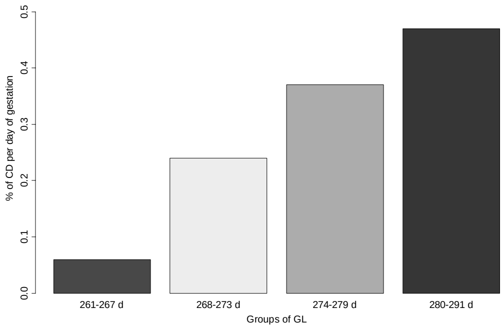
where: λ_{CDGL} is the rate of change in liability to CD when GL changes by 1 d, λ_{SBGL} is the rate of change in liability to SB when GL changes by 1 d, and λ_{SBCD} is the rate of change in liability to SB when liability to CD changes by 1 unit.

Results

Posterior means of direct and maternal heritability of GL were 0.39 and 0.08, respectively. Direct and maternal heritability estimates, respectively, were 0.08 and 0.07 for CD and 0.07 and 0.10 for SB. Genetic correlations between direct effects for GL and CD were moderate, positive and slightly higher than those between maternal effects for GL and CD. Genetic correlations of different magnitude and sign were obtained between direct effects for GL and SB, depending on GL phenotype. The posterior mean was negative for GL ≤ 267 d, nil for GL between 268 and 273 d, nil for GL between 274 and 279 d, and positive for GL ≥ 280 d. Posterior means of genetic correlations between maternal effects for GL and SB were negative in the first three subclasses but were nil for GL ≥ 280 d. The nonlinear genetic relationship between direct genetic effects for GL and SB might explain why other studies, such as HANSEN *et al.* (2004), found very weak genetic associations between GL and SB using a standard multiple-trait mixed model. Large and positive estimates were obtained for the genetic correlation between direct effects for CD and SB, and these were similar in each of the four GL subclasses. The posterior mean of the maternal genetic correlation between CD and SB was also positive, although slightly smaller in magnitude.

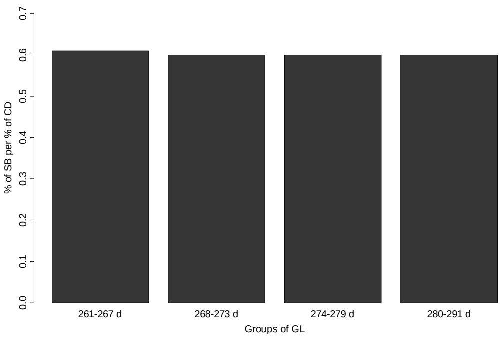
Examination of structural coefficients allows calculation of the expected change in CD per unit change in GL, as well as the expected change in SB per unit change in CD or GL. As shown in Figure 1, for cows with GL ≤ 267 d, an extra day of GL would not increase CD. However, rates of change were positive for the other classes, indicating that CD would increase by 0.24%, 0.37% and 0.47% for each additional day of GL.

Figure 1. Change in expected percent of CD per extra day of GL, for each GL class.



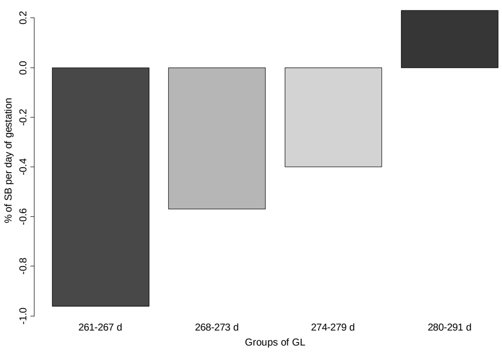
Conversely, the relationship between CD and SB is unaffected by GL, as shown in Figure 2. Positive estimates obtained for all GL classes indicate that the rate of SB increases by approximately 0.60% if the incidence of CD increases by 1%, regardless of GL.

Figure 2. Change in expected percent of SB per extra percent of CD, for each GL class.



The total effect of GL on SB reflects the direct effect of GL on SB, as well as an indirect effect modulated through the effect of GL on CD and the effect of CD on SB. As shown in Figure 3, the rate of SB is expected to decrease by 0.96%, 0.57%, and 0.40%, respectively if GL increases by 1 day in first three GL classes. However, for GL ≥ 280 d, an additional 1 day of GL would increase the incidence of SB by 0.23%.

Figure 3. Change in expected percent of SB per extra day of GL, for each GL class.



Implications

Application of a recursive model in a trivariate analysis of calving traits accommodated nonlinear relationships between GL phenotype and liabilities to CD and SB. In addition, it was possible to disentangle and quantify direct and indirect recursive effects. A nonlinear correlation was detected between direct genetic effects for GL and SB. Low genetic correlations between GL and liabilities to CD and SB, which arise due to nonlinear relationships between these traits, suggest that inclusion of GL in a conventional multiple-trait model would not greatly enhance selection for reduced CD or SB. However, GL is an important trait that should be considered in breeding programs, because of its genetic and phenotypic associations with CD and SB. On one hand, short GL are associated with high incidence of SB and low incidence of CD. On the other hand, long GL are associated with high incidence of both CD and SB. In order to minimize the incidence of both CD and SB, an intermediate optimum for GL in the range of 273 to 275 d may be optimal from an economic standpoint and an animal well-being point of view.

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