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Direct and maternal genetic relationships between calving ease, gestation length, milk production, fertility, type, and lifespan of Holstein-Friesian primiparous cows

S. A. E. Eaglen,*†[1] M. P. Coffey,* J. A. Woolliams,† and E. Wall*
*Animal and Veterinary Sciences Group, Scottish Agricultural College (SAC), Roslin Institute Building, Easter Bush, Midlothian, EH25 9RG, United Kingdom
†The Roslin Institute and Royal (Dick) School of Veterinary Studies, University of Edinburgh, Roslin Institute Building, Midlothian, EH25 9RG, United Kingdom

ABSTRACT

As the emphasis in cattle breeding is shifting from traits that increase income toward traits that reduce costs, national breeding indices are expanding to include functional traits such as calving ease (CE). However, one issue is the lack of knowledge of genetic relationships between CE and other dairy traits. The same can be said about gestation length (GL), a potential novel selection trait with considerable heritabilities and possible genetic relationships with the calving process. This study aimed to estimate the genetic relationships between CE, GL, and other dairy traits of interest using a national data set of 31,053 primiparous cow performance records, as well as to separate direct and maternal genetic effects. Chosen dairy traits included fertility (calving interval, days to first service, nonreturn rate after 56 d, number of inseminations per conception), milk production (milk yield at d 110 in milk, accumulated 305-d milk yield, accumulated 305-d fat yield, accumulated 305-d protein yield), type (udder depth, chest width, rump width, rump angle, mammary composition, stature, body depth), and lifespan traits (functional days of productive life). To allow the separation of direct and maternal genetic effects, a random sire of the calf effect was included in the multitrait linear trivariate sire models fitted using ASReml. Significant results showed that easily born individuals were genetically prone to high milk yield and reduced fertility in first lactation. Difficult calving primiparous cows were likely associated with being high-producing, wide and deep animals, with a reduced ability to subsequently conceive. Individuals that were born relatively early were associated with good genetic merit for milk production. Finally, individuals carrying their offspring longer were genetically associated with being wide and large animals that were themselves born relatively early. The study shows that it is feasible and valuable to separate direct and maternal effects when estimating genetic correlations between calving and other dairy traits. Furthermore, gestation length is best used as an indicator trait for lowly heritable calving traits, rather than as a novel selection trait. As estimated direct and maternal genetic correlations differ, we can conclude that genetic relationships between CE, GL, and traits of interest are present, but caution is required if these traits are implemented in national breeding indices.
Key words: calving ease, gestation length, genetic correlation, milk production

INTRODUCTION

Worldwide, awareness is growing that, to maintain or improve economic efficiency, an emphasis on the genetic merit for functional traits is needed when selection decisions are made (Amer, 2012; Boichard and Brochard, 2012). Furthermore, the negative genetic relationships that are observed between production and functional traits have made it essential for functional traits to be included in national breeding indices to stop undesirable genetic trends on correlated traits.

Calvings are crucial events on a dairy cattle farm with complications leading to potential loss or impaired performance of the cow and calf and compromised animal welfare (Dematawewa and Berger, 1995; Lombard et al., 2007; Eaglen et al., 2011; Barrier et al., 2012). Under some assumptions, additional labor and veterinary costs cost the UK dairy cattle industry approximately £110 for a calving of moderate difficulty and £400 for one that is severe (McGuirk et al., 2007). With current incidences in the United Kingdom of 24 and 4% for moderately and severely difficult first calvings, respectively, calving ease (**CE**) is an economically important functional trait (Eaglen et al., 2011). Hence, if genetic selection could aid in reducing the number of difficult calvings, it would be of great benefit to the dairy cattle industry.

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[1]Corresponding author: sophie.eaglen@sac.ac.uk

Although the observed genetic variance for CE is low, genetic progress can be made. Consequently, CE is increasingly being introduced as a selection trait; the first CE proofs in the United Kingdom were officially released in 2010 (Wall et al., 2010). A genetic evaluation of CE automatically raises the question of the relationship of CE with existing selection traits. The phenotypic relationships of CE and selection traits such as milk production and fertility are frequently reported and signify the importance of this trait (e.g., Eaglen et al., 2011). However, genetic evaluations require knowledge of the underlying genetic relationships to avoid making genetic progress in CE while jeopardizing gains in other traits, and vice versa. Such published information is noticeably lacking. The estimation of genetic correlations in case of a maternal trait such as CE is complicated by a genetic maternal component. Statistical models must allow the estimation of multiple genetic (co)variances per trait rather than a single additive genetic variance (Willham, 1963). Estimation of only a direct or a maternal correlation is likely to result in bias (Willham, 1980; Meyer, 1992). A variety of approaches has been taken to avoid this problem (Ali et al., 1984; Dadati et al., 1985; Muir et al., 2004). However, to our knowledge, only 2 studies have attempted to estimate genetic correlations by actually separating direct and maternal effects and allowing for the appropriate covariance structure. First, Cue et al. (1990) presented genetic direct and maternal correlations of CE with type traits in a model in which sires were assumed to be unrelated, which is likely to have affected the capability of the model to separate all variance components. Second, López de Maturana (2007) separated direct and maternal effects with pedigree included to estimate the genetic relationships between CE, milk yield, and fertility.

Besides CE, stillbirth and gestation length (**GL**) have been evaluated for associations with the calving event. In the United Kingdom, stillbirth has little detectable genetic variation, whereas GL has been shown to be moderately heritable in both its direct and maternal components, which allows for potential genetic selection (Norman et al., 2011; Eaglen et al., 2012). Gestation length might affect the dairy cattle industry by affecting calving interval (**CI**) and milk yield (Hageman et al., 1991; Norman et al., 2011) but reports of genetic correlations between GL and traits of economic importance to dairy production are scarce. Moreover, to our knowledge, the separate direct and maternal genetic relationships of GL with other traits of interest have not yet been studied.

In summary, reliable information is lacking on what may be expected when CE or GL is emphasized in selection indices, beyond the improvement of the trait itself. This study has the objective, therefore, of estimating the genetic correlations between CE, GL, and established dairy traits, such as fertility, milk production, and type and lifespan traits, using models that allow the full separation of direct and maternal effects.

MATERIALS AND METHODS

Direct and Maternal Effects

This study follows Willham (1963), which models the phenotype (P_i) for a maternally affected trait as

$$P_i = A_{D,i} + E_{D,i} + A_{M,j} + E_{M,j}, \qquad [1]$$

where the maternal effect is property of dam j, which is expressed in the phenotype of offspring i. Thus, in the life of individual i, the direct additive effect ($A_{D,i}$) is expressed at the start of life, whereas, when i is female, the maternal additive effect ($A_{M,i}$) is expressed whenever i calves. The environmental effects on P_i are represented in Equation [1] by the direct environmental effect ($E_{D,i}$), which is property of offspring i, and the maternal environmental effect ($E_{M,j}$), which is property of dam j.

Therefore, when referring to the direct breeding effect of CE (*CEd*) or GL (*GLd*), one is addressing the ease of birth or the length of gestation before *being born*, respectively. When the maternal effect of CE or GL is mentioned (*CEm* or *GLm*), this refers to CE or GL before *calving*, respectively.

Data Description

This study was restricted to first-parity CE records that were collected from 1995 to 2009 by 2 milk recording organizations in the United Kingdom. Data editing is described in detail by Eaglen et al. (2012) but major edits included a restriction on single-birth calvings and age of dam (18 to 48 mo) and a correction on the standard deviation of CE score within the herd-year contemporary group.

Gestation length was calculated from the last recorded insemination and calving date and was restricted to between 265 and 295 d. Calving ease was scored on a categorical scale that differed between the 2 data sources (a 4-point scale vs. a 5-point scale). The scales were therefore harmonized as explained in Eaglen et al. (2011). Subsequently, to account for their categorical nature, the scores were transformed to values on the underlying normal distribution (liability scale), as described in Eaglen et al. (2012). The frequency distribution of CE scores in the data set can be found in Table 1.