Estimations of genetic correlations between energy balance and days open in Holsteins in Japan

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Summary

It is important to improve the energy balance (EB) of dairy cows in lactation to prevent the deterioration of health and fertility. Here, we estimate the genetic correlations between EB and days open (DO) in Holsteins in Japan. The data consisted of test-day milk records for the first lactations of Holstein cows calving in 2010-2013. The data set for analysis consisted of 2,279,906 records of 247,487 cows. EBs were estimated by using the multiple regression equations of Friggens et al. (2007) and Løvendahl et al. (2010). Genetic parameters of EBs and DO were estimated by using a random regression model. Estimated EBs were negative soon after parturition and changed to positive at about 50 days in milk (DIM). The phenotypic values of DO were greater in lower Friggens EB classes or lower Løvendahl EB classes from 36 to 65 DIM. The heritability estimates of EBs were about 0.2 and almost constant throughout lactation. The heritability estimate of DO was 0.07. The genetic correlations between EBs and DO were strongest soon after parturition, at about -0.3, and then weakened to -0.1 to 0 after 200 DIM. In conclusion, it should be possible to decrease DO—that is, to improve reproductive performance—by improving EB.

Keywords: dairy cow, energy balance, random regression model, reproduction

Introduction

In the last few decades, increasing milk yields in dairy cows have led to postpartum energy deficits (Hüttmann *et al.*, 2009). These deficits occur because the energy input from feed intake cannot compensate for the energy output from the increasingly high milk production in early lactation (de Vries *et al.*, 1999). Negative energy balance (EB) causes reproductive problems, mastitis, and metabolic diseases such as ketosis (Ingvartsen *et al.*, 2003).

The concentrations of milk components such as fat or protein are affected by the energy status of the cow. The fat to protein ratio (FPR), in particular, has been suggested to be a potential indicator of EB (Friggens *et al.*, 2007). Friggens *et al.* (2007) and Løvendahl *et al.* (2010) suggested multiple regression equations for estimating EB by using milk composition parameters as independent variables. Our objective here was to show the effect of EB on reproduction in dairy cows by using a random regression test-day model to estimate the genetic correlation between EB (as estimated by using multiple regression equations) and days open (DO).

Materials and methods

Data

The data consisted of test-day milk records for the first lactations of Holstein cows calving in 2010-2013. Records were collected by the Livestock Improvement Association of Japan. All lactation records of cows aged 18 to 35 months covered days in milk (DIM) 6 to 305. All cows were aged 20 to 46 months at the time of first insemination and were inseminated for the first time within 365 days after calving. There was more than one cow for each herd first insemination year class and each herd test day class. Data from cows with unknown parents were removed. The pedigree data used for the analysis were traceable back through three generations of cows with records. There were 2,279,906 records from 247,487 cows and 684,708 pedigrees. Analysis using all of the data was impossible because of computational difficulties, so we divided the herds into 10 subsets at random.

Estimation of EB

Two types of EB values—Friggens (EBF) and Løvendahl (EBL)—were estimated by using the equations of Friggens *et al*. (2007) and Løvendahl *et al*. (2010), as follows;

where diff() is the current minus the previous value.

We used test-day data for analysis, so the data were not recorded every day but once a month. Then we treated diff() as the differential of the current minus the previous test day value divided by the days between the current and the previous test day.

Phenotypic relationship

The average DOs in the different EBF or EBL classes were calculated in the different DIM classes. EBF or EBL was divided into 10 classes: low (under -30 MJ/day), from -30 to 50 MJ/day in 10-MJ/day increments, and high (over 50 MJ/day). DIM was divided into nine classes from 36 to 305 days in 30-day increments.

Random regression analysis

Genetic parameters were estimated by using a random regression model, as follows:

where is the estimated EB; is the fixed effect of the hth herd test day; is the fixed regression coefficient of the ith region calving month corresponding to the mth-order polynomial; is the fixed regression coefficient of the jth calving age (in months), corresponding to the mth-order polynomial; is the Legendre polynomial of order m (m = 0 to 4) and Wilmink's exponential function (exp(-0.05t); m = 5) for *t* DIM; is the mth-order additive genetic random regression coefficient of the kth animal; is the mth-order permanent environmental random regression coefficient of the lth animal; is the random residual effect; is the observation of DO; is the fixed effect of the pth herd year at the first insemination; is the fixed effect of the qth month at the first insemination; is the fixed effect of the rth age (in months) at the first insemination; is the additive genetic effect of the kth animal; is the permanent environmental effect of the lth animal; and is the random residual effect.

The Gibbs3f90 program (Misztal *et al*., 2002) was used to estimate variance-covariance components. A single chain of 100,000 samples was generated, and 50,000 samples after a burn-in period of 50,000 cycles were used to estimate posterior means for the model parameters.

Results and discussion

The estimated EBF and EBL at DIM 30 were -23.1 and -22.4 MJ/day, respectively. These values were positive at 52 and 48 DIM and dropped to 30.6 and 24.8 MJ/day by 305 DIM. These EB values and changes throughout lactation were similar to those calculated from the energy input and output (Hüttmann *et al*., 2009; Spurlock *et al*., 2012; Gaillard *et al*., 2016). Thus our estimated EBs reflected the cows' energy status.

The phenotypic values of DO were greater in lower EBF or EBL classes from 36 to 65 DIM (Figure 1). The same trends were apparent from 66 to 95 DIM and 96 to 125 DIM, but in these cases DO was greater not only in the lower EB classes but also in the overly high EB (over 40 MJ/day) classes. Low reproductive performance might thus have been caused by low EB in early lactation, and also by overly high EB in mid- to late lactation.

The heritability estimates of EBF and EBL were 0.20 to 0.23 and 0.19 to 0.21, respectively, and were almost constant throughout lactation (Figure 2). These values were similar to those estimated by using EBs calculated from energy input and output (Banos & Coffey, 2010; Buttchereit *et al*., 2011; Spurlock *et al*., 2012). The heritability estimate of DO was 0.07 in both the EBF model and the EBL model. These values were similar to the heritability estimate (0.053) reported by Hagiya *et al*. (2014) for DO in Holsteins in Japan between the first and second parities.

The genetic correlations between EBF or EBL and DO were strongest soon after parturition, at -0.34 and -0.33, respectively (Figure 3). These values weakened as the lactation stage increased, reaching -0.05 to 0.00 between EBF and DO and -0.10 to -0.01 between EBL and DO after 200 DIM. These results showed that longer DO was caused by lower EB in early lactation, whereas DO had almost no genetic relationship with EB in late lactation. The average DO was 139. If we surmise that EB not after conception, but before conception, affects DO genetically, then these results can be considered appropriate. Banos and Coffey (2010) estimated negative genetic correlations of -0.28 to -0.64 between EB and DO; their correlations were strong in late lactation. Puandgee *et al*. (2016) estimated genetic correlations of -0.04 to 0.18 between DO and FPR as an index trait of EB; their correlations were strong in early lactation and weakened to about zero in late lactation.

Conclusions

Our heritability estimates for EB were about 0.2 throughout lactation, so it should be possible to improve EB genetically. The estimated genetic correlations between EB and DO were about -0.3 in early lactation, so it should be possible to decrease DO—in other words, to improve reproductive performance by improving EB.

Acknowledgments

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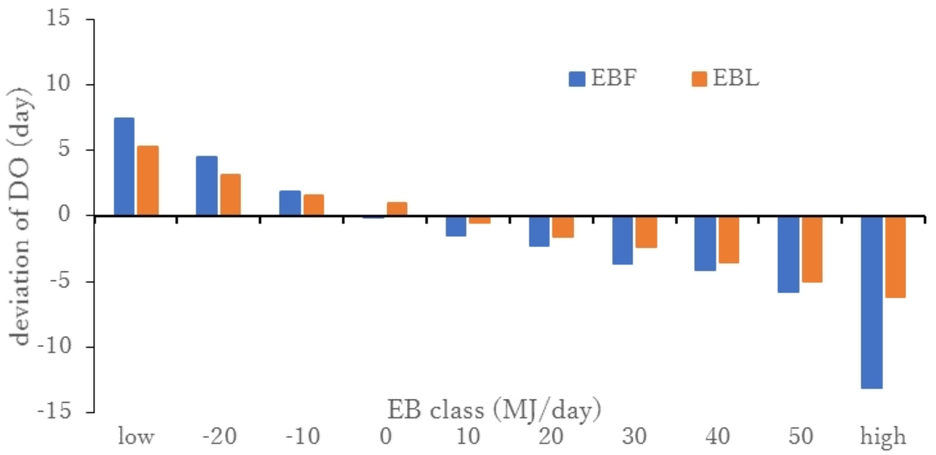

Figure 1. Averages of days open (DO) of cows in 10 energy balance (EB) classes, as estimated by using the equations of Friggens (EBF) and Løvendahl (EBL) from 36 to -65 DIM. DOs are deviations from averages of all cows at the same DIM.

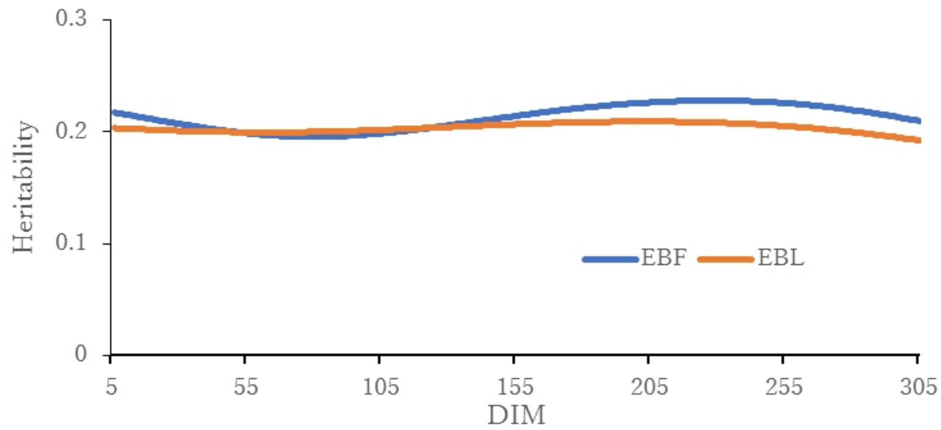

Figure 2. Changes of heritability of energy balance estimated using the equation of Friggens (EBF) and Løvendahl (EBL) across days in milk (DIM).

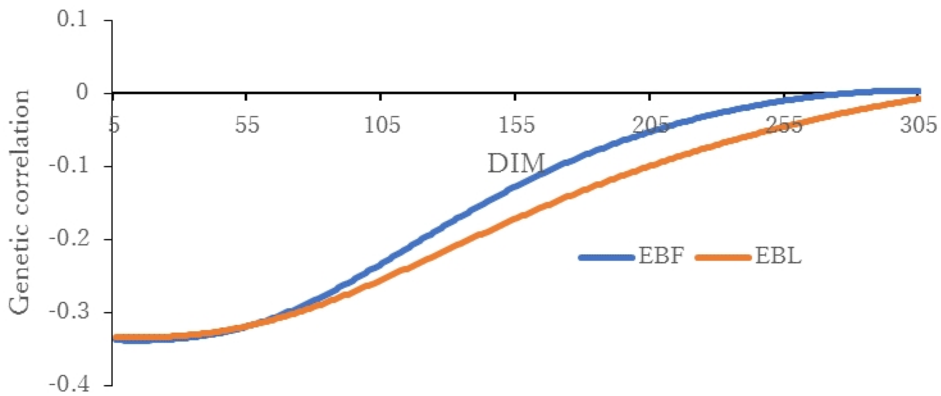

Figure 3. Changes of genetic correlations between energy balance estimated using the equation of Friggens (EBF) or Løvendahl (EBL) and days open across days in milk (DIM).