ABSTRACT: The energy balance (EB) in the first three lactations of Japanese Holsteins were calculated, and the genetic parameters of EB were estimated using a multiple-trait random regression model. EB was negative soon after parturition and positive around days in milk (DIM) 60 in all parities. Heritability estimates of EB were within the range of 0.15–0.25 soon after parturition and highest in the 1st parity, particularly during the early stage of lactation. Genetic correlations of EB among parities were estimated to be within the range of 0.4–0.6 soon after parturition and the lowest between the 1st and 3rd parities. Genetic correlations between EB and milk yield were negative until DIM 75–105. Genetic correlation between EB and SCS in the 1st parity was -0.15 soon after parturition. The results of the genetic evaluation may help in improving EB of dairy cows.

Keywords: dairy cow; energy balance; random regression test-day model

Materials and Methods

Data. The data consisted of test-day milk records of Japanese Holstein cows that were collected by the Livestock Improvement Association of Japan from 2000 to 2008. All lactations in the first three parities were from days in milk (DIM) 6 to 305 and were required to have a minimum of 8 records. Some cows had records from two or more parities, and so the data set for analysis consisted of 604,147 records of 48,360 cows (258,778 records of 28,473 first parity cows, 201,075 records of 22,235 second parity cows, and 144,294 records of 15,901 third parity cows). Pedigree data used for the analysis consisted of 86,539 animals, traced back three generations from cows with records. The traits used for the calculation of EB and the estimation of genetic parameters included milk yield, milk fat content, milk protein content, and somatic cell score (SCS).

Calculation of EB. EB was calculated using the following multiple regression equation of Friggens et al. (2007):

$$\begin{align*}
\text{EB} &= 82.4 + 0.065 \times \text{DIM} + 5.00 \times \text{MFC} - 80.5 \times \text{FPR} \\
&\quad - 94.4 \times \text{diff(MY)} + 1365.8 \times \text{diff(mPY)} + 200.4 \times \text{diff(FPR)} \\
\end{align*}$$

where MFC is the milk fat content (%); FPR is the fat to protein ratio; MY is the milk yield (kg); mPY is the milk protein yield (kg); and diff(trait) is the current minus the previous test-day value of the trait per day.

Multiple-lactation analysis. Genetic parameters of EB and milk traits were estimated using a multiple-trait random regression model, in which the records within and between parities were treated as separate traits. The model is presented using the following equation:

$$\begin{align*}
y_{ijklms} &= \text{HTD}_{lms} + \sum_{m=0}^{5} \text{RAS}_{jmns} x_{ms}(t) \\
&\quad + \sum_{m=0}^{3} a_{kms} x_{ms}(t) + \sum_{n=0}^{3} p_{e_{lms}} x_{ms}(t) + e_{ijklms}
\end{align*}$$

where $y_{ijklms}$ is the observation; HTD$_{lms}$ is the fixed effect of the $i$th herd-test-day; RAS$_{jmns}$ is the fixed regression coefficients of the $j$th region-age-season subclass of the $s$th
trait in the $n$th parity (2 classes of region; Hokkaido and the other regions, 13 classes of the age of months for each parity; 20–32 months for the first parity, 33–45 months for the second parity, and 46–58 months for the third parity, 4 classes of seasons; January to March, April to June, July to September and October to December) corresponding to the $m$th-order polynomial; $x_{ms}(t)$ is the $m$th-order Legendre polynomial coefficients ($m = 0–4$) and Wilmink’s exponential function [$\exp(-0.05t)$; $m = 5$] for DIM $t$ of the $s$th trait; $a_{kmns}$ is the $m$th-order additive genetic random regression coefficients of the $s$th trait of the $k$th animal in $n$th parity; $pe_{kmns}$ is the $m$th-order permanent environmental random regression coefficients of the $s$th trait of the $l$th cow in $n$th parity; and $e_{ijklns}$ is the random residual effect.

The Gibbs2f90 program (Misztal (2002)) was used to estimate the 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 the posterior means of the parameters of the model.

**Results and Discussion**

The calculated EB at DIM 30 was -21.5, -32.4, and -33.0 MJ/day in the 1st, 2nd, and 3rd parity, respectively (Figure 1). These were positive at DIM 63, 59, and 59, and peaked at DIM 97, 64, and 95 in the 1st, 2nd, and 3rd parity, respectively. EB in the 1st parity was almost constant after the peak, but that in the 2nd and 3rd parities slowly decreased in the middle stage of lactation and remained constant after DIM 180. EB was lower in the 2nd and 3rd parities compared to the 1st parity until DIM 60 when the EB was negative and higher after DIM 60 when the EB was positive. These changes throughout lactation and differences in EB among parities were similar to those that were estimated from the energy input and output (de Vries et al. (1999); Coffey et al. (2004); Spurlock et al. (2012)), thus the calculated EB in this study reflects the energy status of the cows. Heritability estimates of EB were 0.25, 0.17, and 0.15 soon after parturition in the 1st, 2nd, and 3rd parity, respectively (Figure 2). These then decreased in all parities and were lower than 0.10 at DIM 80, 60, and 46 in the 1st, 2nd, and 3rd parity, respectively. These were within the range of 0.07–0.12 from DIM 60 to 250, and increased again to 0.21, 0.19, and 0.18 at DIM 305 in the 1st, 2nd, and 3rd parity, respectively. Hüttmann et al. (2009) estimated the heritabilities of EB in the 1st lactation of Holsteins using the random regression model as 0.34, 0.18, 0.06, 0.04, and 0.15 in DIM 11–30, 31–60, 61–90, 91–150, and 151–180, respectively. Spurlock et al. (2012) reported that the heritability estimates of EB during the 1st to 7th lactations of Holsteins using a random regression model increased to 0.25 soon after parturition and then decreased to less than 0.10 after DIM 90. Changes in heritability estimates of EB throughout lactation in our study were similar to those of previous studies. Heritability estimates of EB were higher in the 1st parity than in 2nd and 3rd parities, particularly in the early stage of lactation, with a maximum difference of 0.1. Genetic correlations of EB among parities soon after parturition were 0.57, 0.60, and 0.36 between the 1st and 2nd, 2nd and 3rd, and 1st and 3rd parities, respectively (Figure 3). These then increased to 0.97–0.99 around DIM 100 in all combinations. The metabolism of primiparous cows differs from that of multiparous cows, including the need for partition energy resources for growth (Spurlock et al. (2012)). The early stage of lactation when a decline in energy balance occurs is the most important stage for the improvement of metabolic status. These differences in the heritabilities and genetic correlations among parities in EB are important to determine the model for genetic evaluation. Genetic correlations between EB and milk yield were -0.32, -0.18, and -0.31 soon after parturition in the 1st, 2nd, and 3rd parity, respectively, then increased thereafter. This result was similar to the findings of Hüttmann et al. (2009), who estimated that the genetic correlation between EB and milk yield in DIM 11–30 as -0.20, which was the lowest throughout lactation. Cows with high milk yield during the early stage of lactation thus often show low metabolic statuses genetically. The genetic correlation between EB and SCS in the 1st parity was negative (-0.15) soon after parturition, which was different from low positive values in the 2nd (0.07) and 3rd (0.01) parities. High positive genetic correlations between SCS and mastitis were estimated (Carlen et al. (2004)), and negative energy balance increases the risk of clinical mastitis during the early stage of lactation (van Straten et al. (2009)). The results of this study suggest that it is possible to improve the energy status of cows that are in the early stage of lactation during the 1st parity, which in turn may improve udder health.

![Figure 1: Predicted energy balance of cows in the 1st, 2nd and 3rd parities across days in milk (DIM)](image-url)
Conclusion

The early stage of lactation plays an important role in improving metabolic status of dairy cows. We may underestimate the energy deficit of primiparous cows by using the repeatability model in analyzing multi-lactation data of EB. The results of this study show that the multiple trait model, in which the records within and between parities are treated as separate traits, is appropriate for the genetic evaluation of EB. Heritability estimates of EB showed intermediate values during the early stage of lactation, and thus it is possible to improve EB genetically. Heritability estimates of EB in the early stage of lactation were higher in the 1st parity compared to the other parities. Genetic correlations of EB among parities were low during the early stage of lactation. Genetic correlations between EB and milk yield or SCS varied across stages of lactation or parities. The energy status of dairy cows may thus be improved through the application of these results to the genetic evaluation of EB.

Literature Cited