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Genetic correlations among female fertility, 305-day milk yield and persistency during the first three lactations of Japanese Holstein cows

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ABSTRACT

The genetic correlations between reproductive traits in cows and milk-production traits (305-day milk yield and lactation persistency) were estimated by using first-lactation records (representing 476,284 Japanese Holstein cows), second-lactation records (380,474 cows), and third-lactation records (267,344 cows). The reproductive traits evaluated were: days from calving to the first insemination (**DCF**); conception rate for the first insemination (**CR**); number of inseminations (**NI**); and days open (**DO**). Persistency was defined as the difference between milk yields at 240 and 60 days in milk. Genetic parameters for reproductive traits (**DCF**, **CR**, **NI**, and **DO**) were estimated within each lactation by using a four-trait animal model. The genetic correlations between reproductive traits and milk-production traits were estimated by using a three-trait (one reproductive trait and two milk production traits) linear model. The genetic correlation estimates within the first lactation were similar to those of the other lactations, suggesting that the genetic relationships among fertility, 305-day milk yield, and lactation persistency were constant over the first three lactations. The genetic correlations among reproductive traits were fairly strong, but those of **DCF** with **CR** and **NI** were relatively weak. Antagonistic genetic correlations, which ranged from 0.17 to 0.39 in absolute value, between reproductive traits and persistency were revealed. Therefore, when selecting to increase lactation persistency, indicators of female fertility have to be included in the genetic evaluation to reduce undesirable side effects on fertility in cows.

1. Introduction

Female fertility is an important factor for improving the lifetime productivity of dairy cattle. Because dairy cow fertility has declined during recent years (Walsh et al., 2011); genetic improvements in female fertility have been initiated in many countries (Phillipsson, 2011). Many reproductive traits have been defined in lactating cows (Jorjani, 2006). Days from calving to the first insemination (**DCF**) indicates the cow's ability to recycle after calving. Conception rate (**CR**) or non-return rate (**NR**) for the first insemination, and number of inseminations (**NI**) indicate

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the cow's ability to conceive. Days open (**DO**) and calving interval (**CI**) are defined as combined traits for these two abilities, i.e., recycling ability and ability to conceive. **CR** and **NR** are defined as binary traits (that is, failure or success). The estimates of heritability for reproductive traits are low, and the values of interval traits (**DCF**, **DO**, and **CI**) are slightly higher than those of binary traits and **NI** (e.g., Abe et al., 2009; Ghiasi et al., 2011; Jamrozik et al., 2005; Veerkamp et al., 2001).

Antagonistic genetic relationships between reproductive traits in cows and milk-yield traits have been reported (e.g., Abe et al., 2009; Dematawewa and Berger, 1998; Hagiya et al., 2013; Veerkamp et al., 2001). In addition, some researchers have estimated the relationships between reproductive traits and lactation persistency (Albarrán-Portillo and Pollott, 2013; Haile-Mariam et al., 2003; Muir et al., 2004; Weller et al., 2006). Lactation persistency (**PER**) is generally defined as the ability to maintain a high level of milk production after peak milk yield (Togashi and Lin, 2003). It has been suggested that improving **PER** could increase total milk yield without increasing metabolic stress in early lactation (Dekkers et al., 1998), thus minimizing one potential source of reduced fertility in cows. There are plans to include **PER** in the Japanese total merit index (Togashi et al., 2012).

Low or slightly positive (undesirable) genetic correlations between **CI** and **PER** have been reported (Albarrán-Portillo and Pollott, 2013; Haile-Mariam et al., 2003; Muir et al., 2004). In contrast, desirable genetic correlations between **PER** and **NR** (Muir et al., 2004) or the inverse of **NI** (Weller et al., 2006) have been reported. However, few studies have estimated the genetic correlations between **PER** and various reproductive traits simultaneously (Muir et al., 2004) over multiple lactations (Weller et al., 2006). The results of such a study could clarify these various relationships between **PER** and reproductive traits in cows.

Therefore, our objective here was to investigate the genetic relationships of several reproductive traits with milk yield and **PER** during the first three lactations in Japanese Holstein cows.

2. Materials and methods

2.1. Data

Insemination records during the first three lactations of Holstein cows whose first inseminations were recorded between 2007 and 2011 were obtained from the Livestock Improvement Association of Japan (Tokyo, Japan), in which about 8800 herds were enrolled. Monthly test day (TD) milk records within 305 days in milk (DIM) were collected through the Dairy Herd Improvement program. The data set for the first lactation consisted of records for 476,284 cows; for the second lactation, 380,474 cows; and for the third, 267,344 cows. Each cow had atleast eight TD records. Age at the first insemination ranged from 18 to 54 months at the first lactation (for second calving), from 30 to 72 months at the second, and from 42 to 90 months at the third. There were 270,155 cows with both first and second lactation record, and were 134,873 cows with both first and third. The pedigree data for the first lactation included data on 955,461 animals; for the second, 802,184 animals, and for the third, 600,268 animals, each representing atleast three generations.

Reproductive traits used for this study were **DCF**, **CR**, **NI**, and **DO** (days from calving to pregnancy). **DCF** ranged from 20 to 200 days. **CR**=1 indicated that the first insemination achieved pregnancy, and 0 indicated otherwise. **NI** was classified into 5 levels (1, 2, 3, 4 or 5, and ≥ 6 times). Records in which **DO** was greater than 365 days (for 16,542 cows in the first lactation, 12,737 in the second, and 8970 in the third) were set to 365 days (Oseni et al., 2004). The number of cows for which pregnancy (or lack thereof) could not be confirmed by using the insemination records was 17,311 in the first lactation, 20,810 in the second, and 17,528 in the third. Several methods for censoring records of fertility traits have been discussed (e.g. Hou et al., 2009). However, the reasons for the unknown pregnancy status of these cows may have included sale, movement across herds, and involuntary culling due to accidents or health disorders. In using the insemination records, we could not clarify the reasons why the data on these cows were censored, so their **DO** data were treated as missing.

Cumulative milk yield within 305 DIM (**MILK**) and **PER** were estimated by using multiple-trait prediction (Schaeffer and Jamrozik, 1996) according to Wilmink's function (Wilmink, 1987). **PER** was defined as the difference between milk yields at 240 and 60 DIM (Yamazaki et al., 2013). Summary statistics for each trait are shown in Table 1.

2.2. Models

The data were analyzed within each lactation by using a multiple-trait linear model, even though threshold models theoretically are more appropriate for analysis of the binary (e.g., **CR**) or categorical (e.g., **NI**) data (Gianola, 1982). However, most routine national genetic evaluations of categorical fertility traits (including those in Japan) are based on linear models (Jamrozik et al., 2005; Liu et al., 2008; Mark, 2004), because analyses by using threshold models require excessive calculation time.

The model used for reproductive traits was:

$$y_{ijklm} = FHY_i + FM_j + FA_k + s_m + u_l + e_{ijklm},$$

where y_{ijklm} is the reproductive trait of cow l; FHY_i is the fixed effect of herd year i for the first insemination (the levels were 38,918 for the first lactation, 37,798 for the second, and 34,905 for the third); FM_j is the fixed effect of month j at the first insemination; FA_k is the fixed effect of age group k at the first insemination with 7 levels (18, 19, 20, 21 to 25, 26 to 30, 31 to 40, and ≥ 41 months); s_m is the random effect of service sire m at the first insemination (the levels were 9825 for the first lactation, 8756 for the second, and 7429 for the third); u_l is the random additive effect of animal l; and e_{ijklm} is a random residual effect associated with y_{ijklm}. The age effect at first insemination was not considered for the third lactation record. The service-sire effect in first insemination was not included in the model for **DCF**.