Genetic parameters of Body Condition Score, Angularity, and Chest-Width in Canadian Holsteins

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INTRODUCTION

In early lactation, increase in feed intake is not sufficient to meet energy requirements of milk production in dairy cattle (Block et al., 2001; Banos et al., 2005; Chebel et al., 2008). Cows therefore enter a negative energy state (Block et al., 2001) in which they mobilize tissue reserves to meet increased energy requirements (Friggens et al., 2004). While this is a normal physiological state for the dairy cow in early lactation, the extent and duration of negative energy balance are related to reduced health and fertility (Butler and Smith, 1989). The correlated response in feed intake is not enough to cover the increase in energy requirements associated with selection for increased milk production (Van Arendonk et al., 1991). Thus, genetically higher producing cows mobilize more tissue reserves than lower producing cows (Veerkamp and Emmans, 1995; Dechow et al., 2002). In other words, high producing cows increase the extent and duration of the negative energy balance state to achieve greater milk production. Selection on increased milk production has resulted in reduced health and fertility of dairy cattle (Veerkamp et al., 2001; Heringstad et al., 2003), resulting in a growing interest in improving these traits in various countries (Miglior et al., 2005). If information on energy balance is taken into account in selection decisions, the indirect and unfavorable effect of increased milk production on health and fertility may be reduced (Koenen et al., 2001; Veerkamp et al., 2001).

Energy balance is difficult to measure directly. Banos and Coffey (2009) showed that indirect measures of body energy, such as body condition score (BCS), have the strongest genetic association with cow fertility (compared to direct measures of body energy). Body condition score is a subjective measure of the amount of stored fat on the body (Edmonson, et al., 1989; Broster and Broster, 1998), and hence may be used to indicate energy balance. BCS may be useful for enhancing selection for improved health and fertility. For instance, cows that experience a greater negative energy balance postpartum, with lower BCS, have delayed onset of first estrus (Harrison et al., 1990; de Vries et al., 1999; Dechow et al., 2001), resulting in a greater interval from calving to first service, and greater days open (Bastin et al., 2010). Also, low BCS has been genetically linked to an increase in metabolic disease and overall poorer cow health (Dechow et al., 2004b; Roche et al., 2009).

This report is an extension of two previous studies that analyzed BCS records collected by Valacta (the milk recording agency of Québec) (Montreal, QC). The rest of the Canadian population of Holsteins must be considered. Since 2006, BCS recording has become a part of the routine classification system performed by Holstein Canada on registered cows of all dairy breeds. It may be possible to use Holstein Canada’s BCS and other type traits along with
Valacta’s BCS for a genetic evaluation of BCS over the lactation. This report therefore looks at the genetic parameters of Holstein Canada’s BCS and other type traits.

DATA

The Holstein Canada classification data file included type traits recorded previous to the new classification system (which began in 2006). However, because BCS is only included in the new system, there was limited connectivity in the data set, and the data structure did not allow for a reliable analysis when the data included type traits recorded prior to 2006. Therefore, only data from the new classification system were used, from round 72 to 79. Traits analyzed were BCS, angularity (ANG), chest-width (CW), height at front end (HFE), body depth (BD), pin width (PW), and stature (STA). Whenever BCS was recorded, all other type traits were also recorded, but BCS was not always recorded with the other type traits. Body condition scores were taken on a scale from 1 (thin) to 5 (fat) (at increments of 0.25). Angularity was taken on a scale from 1 (non-angular, close ribs) to 9 (very angular, open ribbed). Chest width was taken on a scale from 1 (narrow) to 9 (wide). Height at front end was taken on a scale from 1 (low) to 9 (high). Body depth was taken on a scale from 1 (shallow) to 9 (deep). Pin-width was taken on a scale from 1 (narrow) to 9 (wide). Angularity, CW, HFE, BD, and PW were taken with unit increments. Stature was a measured trait taken in cm.

Only first lactation classifications were kept, with no reclassification records included. Each classifier’s first round of BCS were removed because it was assumed that these would be recorded less accurately, as they were still learning to score a new trait. The formation of age×stage (AS) classes was similar to Canadian Dairy Network’s method. Specifically, age at calving was limited to 21 to 40 months, and stage of lactation from 1 to 10, with stages ≥11 grouped together in the 11th class. Because BCS was the limiting trait, herds were edited to have BCS records available in ≥6 of the 8 classification rounds, with ≥5 BCS records per round. After edits, 788 herds were left, with an average of 102 cows per herd. There were 80,499 cows with data, and 358,271 animals in the pedigree. There were 3,424 sires with an average of 24 daughters per sire. All 80,499 records were used to analyze BCS with ANG and CW. A second, preliminary study was performed with a random selection of 50 complete herds, and analyzed all 7 traits together.

VARIANCE COMPONENT ESTIMATION

Variance components were estimated using DMU software (Madsen and Jensen, 2008) by a Bayesian approach via Gibbs sampling. Prior values were set arbitrarily to 0.03 for variances and 0 for covariances. Posterior means of (co)variance components were estimated using 80,000 samples after a burn-in of 20,000 samples.

MODEL

The following model was used:

\[ y = X\beta + Z\alpha + e, \]

where \( y \) was the vector of observations for BCS, ANG, and CW, or (for the second analysis) all 7 traits; \( \beta \) was the vector of the fixed effects for herd×round×classifier (HRC) and AS; \( \alpha \) was the vector for random additive genetic effect; \( e \) was a vector of random residuals; and \( X \) and \( Z \) were incidence matrices assigning observations to effects.
Expectations and covariance structure for random effects are:

\[ E(\mathbf{y}) = \mathbf{Xb}, \ E(\mathbf{a})=0, \ E(\mathbf{e})=0 \]

and

\[ \mathbf{V}(\mathbf{a})= \mathbf{A} \otimes \mathbf{G}_0, \ \mathbf{V}(\mathbf{e})=\mathbf{E}, \]

where \( \otimes \) is the Kronecker product function (Searle, 1982), \( \mathbf{A} \) is the additive relationship matrix, \( \mathbf{G}_0 \) is the additive genetic (co)variance matrix, and \( \mathbf{E} \) is the 3×3 random residual matrix. Random effects were assumed to be normally distributed.

**RESULTS AND DISCUSSION**

For the first analysis, concerning BCS, ANG, and CW, estimates of heritabilities, genetic correlations and phenotypic (Pearson) correlations among traits are in Table 1. All phenotypic correlations were significant (P<0.0001). Heritabilities of ANG and CW used as parameters for genetic evaluations of Holsteins in Canada are 0.26 and 0.22, respectively (Interbull, 2010). Those estimates were based on data from the old classification system. Heritabilities were similar, though lower, in this study, and were based on records from the new classification system. A recent study at CDN found that, as of May 2007, parameters estimated with data from the new classification system were overestimated, though these estimates decreased when a year’s worth of data was added to the analysis (Huapaya and Kistemaker, 2009). These results indicated that the depth of data has a major impact on heritability estimates. As of August 2008, they found heritability estimates were 0.28, 0.30, and 0.26 for BCS, ANG, and CW, respectively. Data used in that study included many more records (471,301 records, with 344,082 of those including BCS), and was edited differently from the current study. Also, the data used in the current analysis extends to records taken in 2010. Holstein heritabilities in the US are higher than in this study: 0.31 for BCS and ANG, and 0.28 for CW (Interbull, 2010). Dechow et al. (2004a) analyzed Holstein USA Inc. classification data, as well as producer recorded BCS data. The classification data included BCS and dairy form (a trait similar to angularity). Heritability was 0.22 for BCS and 0.25 for dairy form. Berry et al. (2004) studied BCS, ANG, and CW, and calculated heritabilities of 0.33, 0.36, and 0.26 for each trait, respectively.

Direction and strength of relationships between traits were similar to the literature. Dechow et al (2004a) found a genetic correlation of -0.73 and a phenotypic correlation of -0.45 between BCS and dairy form, which were similar to correlations between BCS and ANG in this study. Like the current study, genetic correlations in Berry et al. (2004) were strongly negative between BCS and ANG (-0.84), and strongly positive between BCS and CW (0.77). Phenotypic correlations in Berry et al. (2004) were negative between BCS and ANG (-0.61) and positive between BCS and CW (0.58), which were stronger than the current study, though in the same direction. While both ANG and CW are strongly genetically correlated with BCS, they are not strongly genetically correlated with each other, which suggests that both traits possess genetic components independent of one another that are in common with BCS. So, both ANG and CW could be used as predictors of BCS.

Results from the first analysis suggest that cows that were genetically inclined to be of lower BCS were more angular, with narrower chests. Previous studies have indicated that cows with an increased extent and duration of negative energy balance (lower BCS) are genetically less fertile (Dechow et al, 2001; Pyrce et al., 2002; Bastin et al., 2010), with increased disease incidence (Dechow et al., 2004b). Indeed, Royal et al. (2002) determined that genetically frailer
cows (more angular, with narrower chests) experienced an extended commencement of luteal activity. Berry et al. (2004) found that genetically wider, more angular cows required more services and had lower pregnancy rates. Berry et al. (2004) also concluded that genetically angular, narrow chested cows have greater SCC. More studies need to be carried out linking type traits like angularity and chest-width to health traits. Preliminary results of the second analysis are provided in Table 2. These results are, again, from the analysis of a random sample of 50 complete herds, so that the total number of records was around 5,000. Results among CW, ANG, and BCS were fairly similar to those of the first analysis. Compared with August 2008 heritability estimates for type traits from the new classification system from Huapaya and Kistemaker (2009), estimates in this study were lower. Again, perhaps this is due to 2 more years’ worth of data in this study, differences in data editing procedures, or number of records included in the analysis (which was substantially greater in Huapaya and Kistemaker (2009)). This analysis will be re-run with more records.

### CONCLUSIONS

Genetically, ANG was strongly negatively correlated with BCS, whereas CW was strongly positively correlated with BCS. All three traits possessed heritabilities that were consistent with the literature. Because of their strong genetic association with Holstein Canada’s BCS, ANG and CW can provide additional information for each cow. All three traits would be useful in conjunction with Valacta’s BCS for an across-lactation genetic analysis of BCS, which would inevitably lead to selection for cattle with improved health and fertility.

### Table 1. Heritability (diagonal), phenotypic (above diagonal), and genetic (below diagonal) correlations among body condition score (BCS), angularity (ANG), and chest-width (CW)

<table>
<thead>
<tr>
<th></th>
<th>BCS</th>
<th>ANG</th>
<th>CW</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCS</td>
<td>0.23</td>
<td>-0.35</td>
<td>0.41</td>
</tr>
<tr>
<td>ANG</td>
<td>-0.72</td>
<td>0.19</td>
<td>0.04</td>
</tr>
<tr>
<td>CW</td>
<td>0.73</td>
<td>-0.19</td>
<td>0.20</td>
</tr>
</tbody>
</table>

### Table 2. Heritability (diagonal) and genetic (below diagonal) correlations among body condition score (BCS), angularity (ANG), chest-width (CW), height at front end (HFE), body depth (BD), pin width (PW), and stature (STA)

<table>
<thead>
<tr>
<th></th>
<th>CW</th>
<th>ANG</th>
<th>HFE</th>
<th>BD</th>
<th>PW</th>
<th>STA</th>
<th>BCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW</td>
<td>0.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANG</td>
<td>-0.32</td>
<td>0.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HFE</td>
<td>0.31</td>
<td>-0.01</td>
<td>0.21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BD</td>
<td>0.70</td>
<td>0.17</td>
<td>0.30</td>
<td>0.31</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PW</td>
<td>0.32</td>
<td>0.03</td>
<td>0.21</td>
<td>0.12</td>
<td>0.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STA</td>
<td>0.38</td>
<td>0.42</td>
<td>0.17</td>
<td>0.20</td>
<td>0.38</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>BCS</td>
<td>0.82</td>
<td>-0.58</td>
<td>0.26</td>
<td>0.38</td>
<td>0.18</td>
<td>0.30</td>
<td>0.26</td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENTS

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REFERENCES


