Genetic parameters for calving ease, gestation length, and birth weight in Charolais cattle

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INTRODUCTION

Calving difficulty (dystocia) is a significant cost to beef production. Dystocia has been associated with calf and cow mortality, increased postpartum interval, and increased veterinary labor costs (Meijering, 1984). Genetic improvement of calving ease (CE) has in some cases been based on the high and positive genetic correlation estimated between dystocia and birth weight (BWT; Koots et al., 1994b), but the use of bulls with low BWT EPD is often associated with decreased growth rates and lighter BW in progeny. Calving ease EPD directly predict the genetic potential for animals to produce calves without difficulty and typically include BWT as an indicator trait, thereby increasing the evaluation accuracy and the numbers of sires evaluated.

The threshold model approach has been applied in many cases to evaluate CE phenotypes (e.g., Wang et al., 1997; Wiggans et al., 2003). However, a scale with 4 or more CE scores tends to rank animals similarly using linear and threshold models (Varona et al., 1999; Ramirez-Valverde et al., 2001; Lee et al., 2002). Snell (1964) suggested a scaling procedure for ordered categorical data such as CE score, which makes the use of a linear model more appealing, especially for large field data sets. Beginning in 2005, the Canadian Charo-
lais Association (CCA) has published CE EPD from a 3-trait model including BWT and gestation length (GEST). In this system, inclusion of GEST as another indicator for dystocia is desirable because of its relative ease of recording and greater heritability (Crews, 2006).

Complete genetic correlations among BWT, transformed CE scores, and GEST have not been published with field data. This study sought to 1) estimate genetic parameters required for genetic evaluation of transformed CE score, including BWT and GEST as indicators, and 2) estimate the genetic trend in CE in the Canadian Charolais population.

**MATERIALS AND METHODS**

Animal Care and Use Committee approval was not obtained for this study because data used were taken from preexisting data in the Canadian Charolais Association Charolais Herd and Record management performance database.

**Data**

A data set \((n = 40,420)\) consisting of BWT, GEST, and CE records from first parity heifers was extracted from the CCA Charolais Herd and Record Management performance database, which included AI and calving date records on animals born between 1979 and 2004. Birth weight records were preadjusted for age of dam and sex of calf effects following procedures outlined by the Beef Improvement Federation (BIF, 2002). The reported breed average for BWT in Canadian Charolais cattle is about \(46 \pm 5\) kg (Crews, 2006). Gestation length was calculated as the number of days between AI mating and birth date, and all GEST records were adjusted for age of dam and sex of calf using estimates reported by Crews (2006). Calving ease records were used for first parity heifers only and were scored as N, U, A, E, H, S, and M. The scores represented a normal or unassisted birth (N, U), assisted or easy pull birth (A, E), hard pull or mechanically assisted birth (H), surgical birth (S), and mal-presentation or dead calf (M). These scores were then converted into numerical scores 1, 2, 3, 4, and 5, respectively. Only animals with phenotypic data for at least 2 of the 3 traits were included in the study. Contemporary groups were constructed as a combination of herd of origin and year of birth subgroups. Groups with less than 10 animals were excluded from analysis because there were many groups with 1 or a few individuals and these mostly represented animals missing data for 2 of the 3 traits. A total of 1,664 groups were obtained, with all ancestral animals without birth date or herd information placed into one contemporary group. The dams were classified into 5 age classes, 2, 3, 4, 5 to 10, and 11 yr or older, according to BIF guidelines (BIF, 2002). The final pedigree included 69,118 animals (Table 1) with year of birth ranging from 1979 to 2004 that comprised at least 2 ancestral generations for animals with records.

**Snell Scores**

To fit a 3-trait linear model involving CE, BWT, and GEST, 14,403 CE phenotypes, recorded as 5 categorical scores from first parity heifers, were transformed to a continuous scale (Snell, 1964). These scores reflect percent unassisted calving (SC). The basic premise is that there exists an underlying continuous distribution of CE scores of which the Snell scores represent class interval midpoints. Snell scores were constructed following the approximation procedure of Snell (1964), which uses a logistic model to obtain scores that can be generalized to a normal distribution. The procedure consists of 3 basic steps.

1. Estimation of class boundaries, \(x_i\), and class interval midpoints (Snell scores, \(s_i\)).
2. Estimation of Snell score means for the various sex of calf \(\times\) age of heifer groups.
3. Scaling of raw Snell scores to range between 0 and 100%.

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**Table 1. Descriptive statistics, means, and SD of variables analyzed**

<table>
<thead>
<tr>
<th>Trait</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of animals</td>
<td>69,118</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of records</td>
<td>40,420</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of contemporary groups</td>
<td>1,664</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of sires</td>
<td>857</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of dams</td>
<td>24,400</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of dams with own record(^1)</td>
<td>5,388</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of first-parity dams with record(^2)</td>
<td>1,782</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trait</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth weight, kg</td>
<td>39,759</td>
<td>46.54</td>
<td>4.79</td>
<td>36.29</td>
<td>80.74</td>
</tr>
<tr>
<td>Gestation length, d</td>
<td>37,663</td>
<td>286.48</td>
<td>4.93</td>
<td>266.00</td>
<td>307.75</td>
</tr>
<tr>
<td>Snell score, %</td>
<td>14,403</td>
<td>83.31</td>
<td>23.30</td>
<td>3.44</td>
<td>100.00</td>
</tr>
</tbody>
</table>

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\(^1\)Number of animals with data for any or all of the traits analyzed.

\(^2\)The dams have birth weight, gestation length, calving ease, or combination of records.

\(^3\)The dams have own calving ease record, as well as one heifer progeny each, with record.
Calving ease evaluation

There being 5 \((k = 5)\) CE categories to be transformed into Snell scores \(s_j\) \((j = 1 \text{ to } 5)\), 6 class boundaries \(x_j\) \((j = 0 \text{ to } 5)\) were estimated. Four groups \((m = 4)\) were constructed based on age of heifer and sex of calf combinations. There were 2 age classes \((2\text- and 3-yr-old heifers)\) and 2 sexes \((\text{male and female})\). Cumulative frequencies, \(p_m\) were obtained for each group, such that Snell score category 5 had a cumulative frequency of 1. Maximum likelihood estimates of the group intervals, \(x_i\), were then obtained for \(x_0 \text{ to } x_4\) to \(x_2 \text{ to } x_1\) intervals using Eq. [5] of Snell (1964).

\[
0 = \frac{N_k}{e^{x_k} - x_{k-1} - 1} + N_{k-1} - \sum_{i=1}^{m} (n_{i,k-1} + n_{i,k}) \hat{p}_{i,k-1},
\]

where \(N_k\) is the total number of animals in the Snell score category \(k\), whereas \(j = k - 1\). \(\hat{p}_{i,k-1}\) is the cumulative frequency for ease category \(j\) and group \(i\). To obtain the value of the class boundaries, the origin, \(x_0\), was arbitrarily set to 0. Snell scores were calculated as the midpoints of the class intervals. However, for the extreme categories, Snell scores \(s_1\) and \(s_5\) were obtained from the relative proportion \((Q)\) of CE score in that category using Snell’s equations below:

\[
s_1 = x_1 - \frac{-(\ln P_1)}{Q_1},
\]

\[
s_5 = x_4 + \frac{-(\ln P_5)}{Q_5},
\]

where \(P_j\) is the probability of a value less than \(x_j\) whereas \(Q\) is the relative proportion of the CE scores in the Snell score category. Snell score means for each group were treated as random for all traits. Calving ease was treated as a trait of the calf and included a permanent environmental effect of the dams of the heifers on the CE of the heifer as an additional random term. The 3-trait model can be represented in matrix notation as

\[
\begin{bmatrix}
y_1 \\
y_2 \\
y_3
\end{bmatrix} = \begin{bmatrix} X_1 & Z_{11} & 0 \\
0 & Z_{22} & 0 \\
0 & 0 & Z_{m,m}
\end{bmatrix} \begin{bmatrix} b_1 \\
a_2 \\
a_m
\end{bmatrix} + \begin{bmatrix} \hat{e}_1 \\
\hat{e}_2 \\
\hat{e}_m
\end{bmatrix},
\]

where \(X, Z_{m},\) and \(Z_{pe}\) are incidence matrices relating records with the fixed effects, direct genetic, maternal genetic, and permanent environment effects, respectively. The vectors \(y_1, y_2, y_3\) contain the BWT (measured on the calf), SC, and GEST (measured on the heifer, but specific to the calf) phenotypes, whereas \(b, a, a_m,\) \(pe,\) and \(e\) contain fixed effects, direct genetic effects, maternal genetic effects, permanent environmental effects, and the random residual, respectively. The expectations of the vectors and (co)variances of the random terms for the model used for SC are as follows:

\[
\begin{bmatrix}
y \\
Ea_m \\
\text{Var}e
\end{bmatrix} = \begin{bmatrix} Xb \\
0 \\
0
\end{bmatrix},
\]

\[
\begin{bmatrix}
a & \text{Symmetric} \\
am_m & \begin{bmatrix} A_o^2 & 0 \\
0 & A_m^2
\end{bmatrix} \\
pe & I_{D_o}^2 \\
e & 0
\end{bmatrix},
\]

The expectations for BWT and GEST models are the same, but without permanent environment effects. Direct genetic, maternal genetic, permanent environment, and residual variances are represented by the terms \(\sigma^2_{a},\)

\(\sigma^2_{am},\) \(\sigma^2_{pe},\) and \(\sigma^2_{e}\), respectively. \(A\) is the numerator relationship matrix of all animals, \(I_o\) is an identity matrix with order equal to the number of dams with progeny with SC records, whereas \(I_r\) is an identity matrix with order equal to the number of animals with records for the particular trait. The inclusion of the permanent environmental effect in the CE model was tested for significance using the likelihood ratio test; \(LR_i = -2 \log_e (L_i/L_0) = 2 \log_2 L_i - 2 \log_2 L_0 \sim x^2 (df = L_i \text{ parameters} \ - \text{L}_0 \text{ parameters})\), with \(L_0\) being the maximum likelihood obtained when the model included the permanent environmental effect and \(L_i\) the maximum likelihood obtained without the effect. Variance components were estimated using ASREML (Gilmour et al., 2006), which uses an average information algorithm. The program also routinely reports log-likelihood sta-
statistics, which were used for model comparison, whereas variance components were used to estimate phenotypic and genetic parameters. The initial values of the variance and covariance parameters for BWT and GEST were fixed to values reported by Crews (2006). The animal variance component represented an estimate of the additive genetic variance \( \sigma_a^2 \), whereas the phenotypic variance \( \sigma_p^2 \) was obtained from the sum of all variance components. Heritability \( h^2 \) was computed as the ratio between the additive genetic and phenotypic variances, whereas \( c^2 \) represented the proportion of phenotypic variance attributable to permanent environmental variance.

**Genetic Trends**

Genetic trends were obtained by regressing average EBV obtained for the 3 traits from the 3-trait analysis on year of birth of the animals, which ranged from 1979 to 2004. Trends were also obtained for all traits by regressing average EBV on year of birth for the period between 1990 and 2004. Further, the animals were ranked based on their EBV, the ones with the most negative values for BWT and GEST, and positive values for SC, having the highest rank. Both Spearman rank correlations and Pearson correlation analyses were performed.

**RESULTS AND DISCUSSION**

Three traits, BWT, GEST, and CE, expressed as SC, were evaluated. Table 1 gives summary statistics observed for these traits. Less than one-half of the animals evaluated had CE data. This number is small because of the imposed condition that allowed only animals with phenotypes for at least 2 traits to be included in the analysis. The mean percentage SC score was high, indicating that a large majority of first parity heifers (72%) calved without assistance (Table 2), similar to estimates obtained by Wang et al. (2005). Only a small proportion of heifers required surgical delivery or bore a dead calf (Table 2). The average GEST was 286.48 d, a result comparable with that observed (285.2 d) by Crews (2006) using a larger data set from the same population. The average BWT was 46.54 kg.

### Table 2. Percent incidence of calving ease categories and the corresponding Snell scores (% unassisted calving, in parentheses)

<table>
<thead>
<tr>
<th>Sex of calf</th>
<th>Age of heifer</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>2</td>
<td>32.26 (100)</td>
<td>12.21 (92)</td>
<td>2.65 (38)</td>
<td>1.71 (23)</td>
<td>0.76 (10)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.62 (92)</td>
<td>0.15 (54)</td>
<td>0.03 (31)</td>
<td>0.00 (16)</td>
<td>0.00 (3)</td>
</tr>
<tr>
<td>Female</td>
<td>2</td>
<td>38.42 (93)</td>
<td>8.28 (55)</td>
<td>1.26 (31)</td>
<td>0.41 (16)</td>
<td>0.58 (3)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.57 (89)</td>
<td>0.08 (51)</td>
<td>0.02 (28)</td>
<td>0.00 (13)</td>
<td>0.00 (0)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>71.87</td>
<td>20.72</td>
<td>3.96</td>
<td>2.12</td>
<td>1.34</td>
</tr>
</tbody>
</table>

**Choice of Models**

It would appear that, for parameter estimation with categorical traits, threshold models perform better because linear models applied to an underlying scale seem to underestimate the parameters (Abdel-Azim and Berger, 1999; Steinbock et al., 2003). However, for field data, the comparative advantages of threshold models over linear models are small (Matos et al., 1997; Phocas and Laloë, 2003; Matilainen et al., 2009), in so far as EBV or EPD estimation is concerned. The ranking of animals using both models is mostly the same (Weller and Ron, 1992). Nonetheless, the accuracy obtained from having 5 categories of CE is still high, even where parameters are underestimated. Further, implementation of threshold models is complicated and computationally expensive and not easily extended to multiple categorical traits within the same analysis (Misztal et al., 1989; Abdel-Azim and Berger, 1999; Ramirez-Valverde et al., 2001; Lee et al., 2002). Threshold animal models have been known to have problems with convergence, leading to biased estimates (Luo et al., 2001). For these reasons, a multivariate linear animal model approach was used. Transformation to Snell scores provides desirable distributional properties ideal for fitting a linear model to CE data (Jamrozik et al., 2005).

Linear models have been routinely used to evaluate categorical traits using an animal model. Gutiérrez et al. (2007) used BWT, CE, calving interval, and weaning weight data in their study, whereas Cole et al. (2007) evaluated 2 categorical traits, CE and still birth. The incorporation of correlated traits such as GEST in addition to BWT should lead to increases in the accuracy of predicted breeding values compared with those obtained through a BWT and CE bi-variate analysis.

Most CE evaluations model direct and maternal genetic effects for all traits. However, only a few studies, such as Eriksson et al. (2004) and Wang et al. (2005), incorporate a permanent environmental effect. In this study, the log-likelihood ratio test was used to test the importance of this effect. The difference in likelihood \((-2\text{LogL})\) observed between the univariate models with and without the permanent environmental effect was 7.62 \((P < 0.005)\). This, along with the fact that the effect accounted for 35% of the total variance, was significant evidence to retain the effect in the model.
Variance Components and Parameter Estimates

The estimate of heritability obtained for GEST was similar to that reported by Crews (2006). However, a lesser value was seen for BWT (Table 3). This is likely due to the fact that the data set used in this study had approximately 4,000 fewer BWT records, as well as a much larger SD. On the other hand, even though there were 3,000 fewer records for GEST, the trait had a much smaller SD and was therefore not affected as much. Heritability estimates for BWT and SC are similar to those obtained by Wang et al. (2005) in their analysis of BWT and SC. The SC estimate was also equivalent to that obtained for French Charolais (0.14) as reported by Phocas and Laloë (2003). The estimates for maternal heritability are shown in Table 3. These estimates for BWT and SC are similar to those obtained by Wang et al. (2005) in their analysis of BWT and SC. The SC estimate was also equivalent to that obtained for French Charolais (0.14) as reported by Phocas and Laloë (2003). The estimates for maternal heritability are shown in Table 3. These estimates for BWT and SC are within the ranges observed in other studies (Koots et al., 1994a; Eriksson et al., 2004; Wang et al., 2005). Generally, reproductive traits such as CE are known to have lesser heritabilities. The results suggest that response to selection for CE would be small, especially for the maternal component.

A review of the literature reveals that many analyses do not fit maternal effects for CE, and, if modeled (Wang et al., 2005), they are not reported. In this study, the estimate of the proportion of phenotypic variance attributable to permanent environment (c^2) was unexpectedly elevated (Table 3), implying that such environmental effects were important for CE. The large c^2 effect is indicative of the influence of the dam of the heifer on the calving ability of the heifer. This would imply that matching dams to sires with appropriate EBV for CE would also help in improving the trait. Eriksson et al. (2004) reported c^2 effects of 5% in Swedish Charolais.

Genetic and Residual Correlations

A wide range of results has been obtained in different studies for genetic correlations, especially involving maternal and direct genetic effects for BWT and CE (or dystocia). The correlation obtained in this analysis (Table 4) was very high, but by no means unique. Correlations ranging from −0.60 to −0.98 have been reported (Koots et al., 1994b; Bennett and Gregory, 2001; Gutiérrez et al., 2007). There were a smaller number of CE records available, compared with BWT records. Also, 74% of animals with CE records had a SC of 90% or greater, with a mean BWT of 44.33 kg compared with the herd average of 46.54 kg. This contributed to the high correlation observed between BWT and SC. Wang et al. (2005) obtained a correlation of −0.67 using BWT and SC.

### Table 3. Variance component and parameter estimates (±SE) for birth weight (BWT), gestation length (GEST), and percent unassisted calving (SC)

<table>
<thead>
<tr>
<th>Model item</th>
<th>BWT, kg</th>
<th>GEST, d</th>
<th>SC, %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variance component</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_p</td>
<td>19.68 ± 0.22</td>
<td>23.1 ± 0.30</td>
<td>428.1 ± 5.75</td>
</tr>
<tr>
<td>V_a</td>
<td>9.08 ± 0.71</td>
<td>14.28 ± 1.02</td>
<td>60.07 ± 10.25</td>
</tr>
<tr>
<td>Cov_a,m</td>
<td>−1.31 ± 0.39</td>
<td>−2.08 ± 0.51</td>
<td>−10.52 ± 6.79</td>
</tr>
<tr>
<td>V_m</td>
<td>2.66 ± 0.32</td>
<td>2.34 ± 0.37</td>
<td>25.89 ± 9.55</td>
</tr>
<tr>
<td>V_e</td>
<td>9.23 ± 0.38</td>
<td>8.61 ± 0.53</td>
<td>201.9 ± 49.08</td>
</tr>
<tr>
<td><strong>Parameter</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>h_a^2</td>
<td>0.46 ± 0.03</td>
<td>0.62 ± 0.04</td>
<td>0.14 ± 0.02</td>
</tr>
<tr>
<td>h_m^2</td>
<td>0.14 ± 0.02</td>
<td>0.10 ± 0.02</td>
<td>0.06 ± 0.02</td>
</tr>
<tr>
<td>c^2</td>
<td>—</td>
<td>—</td>
<td>0.35 ± 0.11</td>
</tr>
</tbody>
</table>

V_p = phenotypic variance, V_a = direct genetic variance, Cov_a,m = direct by maternal genetic covariance, V_m = maternal genetic variance, V_e = permanent environmental variance, V_r = residual variance, h_a^2 = direct heritability, h_m^2 = maternal heritability, c^2 = proportion of phenotypic variance due to permanent environmental effects.

### Table 4. Estimates of genetic correlations (±SE) obtained from the 3-trait analysis of birth weight (BWT), gestation length (GEST), and percent unassisted calving (SC)

<table>
<thead>
<tr>
<th>Model item</th>
<th>BWT</th>
<th>GEST</th>
<th>SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>BWT_d</td>
<td>−0.27 ± 0.06</td>
<td>0.43 ± 0.04</td>
<td>−0.93 ± 0.04</td>
</tr>
<tr>
<td>BWT_m</td>
<td>−0.26 ± 0.06</td>
<td>0.72 ± 0.07</td>
<td>0.15 ± 0.11</td>
</tr>
<tr>
<td>GEST_d</td>
<td>−0.36 ± 0.06</td>
<td>−0.38 ± 0.08</td>
<td>0.17 ± 0.12</td>
</tr>
<tr>
<td>GEST_m</td>
<td>0.01 ± 0.13</td>
<td>−0.49 ± 0.17</td>
<td>−0.27 ± 0.14</td>
</tr>
</tbody>
</table>

BWT_d = direct birth weight, BWT_m = maternal birth weight, GEST_d = direct gestational length, GEST_m = maternal gestational length, SC_d = direct percentage unassisted calving, SC_m = maternal percentage unassisted calving.
Even though the correlation observed between SC and GEST (−0.38 ± 0.08) for direct genetic effects was smaller than that with BWT, the estimate obtained was greater than that observed by Lee et al. (2002), and by Jamrozik et al. (2005) for CE as a trait of the heifer. These 2 studies obtained correlations of 0.22 and 0.19, respectively (the signs are different due to different definitions of CE). The correlations between direct and maternal effects among the different traits were negligible to moderate, ranging from 0.01 between maternal GEST and direct SC to 0.26 between maternal SC and direct BWT (Table 4).

The correlation of maternal effects of SC and GEST was greater than that between direct effects. Similarly, the correlation between maternal effects of BWT and GEST was greater than that for direct effects. This implies an important maternal component in the association between these traits. The genetic correlation between maternal and direct genetic effects for BWT was smaller than those reported elsewhere (Phocas and Laloë, 2003; Crews, 2006), but similar to Wang et al. (2005), whereas the GEST estimate obtained was within the range of those observed in related studies, such as Phocas and Laloë (2003), Eriksson et al. (2004), and Wang et al. (2005). Differences in the magnitude of correlations observed between this study and the others referenced above can be attributed to the use of a 2-trait model or inclusion of different traits in the analysis. Further, the initial variance and covariance parameters for BWT and GEST used for the 3-trait analysis in this study were fixed to values reported by Crews (2006) because these are used for the national cattle evaluation in Canada. The negative genetic correlation between direct and maternal effects for SC (Table 4) is indicative of an antagonistic relationship and can be attributed to physiological and biological factors of the heifer, such as size of pelvic opening (Bennett and Gregory, 2001; Phocas and Sapa, 2004). In their analysis of CE, Phocas and Sapa (2004) treated CE as a trait of the dam.

Estimates of residual correlations ranged from small to moderate. Residual correlations between SC and GEST were negligible (−0.04 ± 0.04), whereas a moderate negative correlation similar to that obtained by Wang et al. (2005) was observed between SC and BWT (−0.35 ± 0.05). The estimate of the correlation between GEST and BWT was small and positive (0.06 ± 0.04).

**Genetic Trend**

Estimated breeding values obtained from the 3-trait analysis were used to rank animals from greatest to least genetic merit. The rank correlations of EBV for

![Figure 1. Genetic trend of average direct estimated breeding value for birth weight (BWT), gestation length (GEST), and percent unassisted calving (SC) for Charolais cattle.](image-url)
direct effects of BWT and GEST with SC were very high (−0.99), suggesting that the ranking of the animals would be the same if any of the 3 EBV were used. However, for maternal effects, the high rank correlation between BWT and SC compared with GEST and SC (−0.76 and −0.49, respectively) would suggest the importance of BWT as an indicator trait for CE over GEST.

Regression of average EBV on year of birth from 1979 to 2004 yielded significant genetic trends for all traits. However, regression of average maternal EBV for BWT, GEST, and SC on year of birth resulted in very small regression coefficients that were not significantly different from zero. There was a significant increase in the average BWT EBV between 1990 and 2004 (Figure 1). All preceding years had an average EBV of zero. The trends for BWT, GEST, and SC had regression coefficients of magnitude −0.06, −0.08, and 0.17, respectively, for 1990 to 2004 and −0.04, −0.08, and 0.10, respectively, when all years were included. The changes in GEST and SC are due to a correlated response of selecting for less BWT because the CCA had not published GEST or CE EPD before 2005. The trends observed for maternal effects for the period 1990 to 2004 were insignificant (Figure 2).

Average direct BWT EBV showed the greatest change, from an average of 0 in 1989 to −2.15 in 2004. Direct GEST and SC EBV followed the same pattern exhibited by direct BWT (albeit in the opposite direction for SC), changing by approximately −1.25 and 2.66 units, respectively. There was no observable change in average maternal EBV as the BWT became progressively less. This is particularly important considering the antagonistic behavior of direct and maternal effects. For the population analyzed, there has been neither preferred selection for direct effects over maternal effects nor use of an index to drive the trends to what is seen in Figures 1 and 2, other than selection using published EPD.

In summary, the genetic evaluation of CE, BWT, and GEST yielded heritability and genetic correlation estimates that were comparable with most studies involving beef cattle breeds. Snell scores expressed as percentage unassisted calving are a useful means of implementing an all-linear genetic evaluation of CE. The antagonistic effect between direct and maternal effects, especially for CE, means that improvement of both effects at the same time could prove a challenge, and selection strategies need to have this in mind. Dekkers (1994) shows that a selection index incorpo-
rating direct and maternal CE EBV, together with use of assortative mating of sires, is an effective strategy in Canadian Holsteins. Permanent environmental effects in the present study were seen to have a significant effect on CE for the Canadian Charolais population and suggest yet unknown effects of the pre- and post-partum environment of the heifer on the unborn calf. Further studies will be needed to clarify the nature and extent of this effect. Though small in magnitude, a genetic trend was observed for BWT and by correlated response for GEST and SC in the population analyzed. However, on average, maternal genetic effects did not show any change. These results suggest that incorporation of BWT and GEST data into CE evaluation can provide a tool for direct and accurate selection for reduced calving difficulty in beef cattle. The high genetic correlations between BWT and CE, for both direct and maternal genetic effects, mean greater CE could also be achieved effectively by selection for less BWT in situations in which CE data are not available or are difficult to obtain. Such a strategy would be limited by the reduction in growth performance that might be expected to accompany decreasing BWT selection, and for this reason, genetic improvement programs should consider both CE and growth.

**LITERATURE CITED**


