The Relationship Between Body Condition Score and Reproductive Performance

J. E. Pryce, M. P. Coffey, and G. Simm
Animal Biology Division, Scottish Agricultural College, West Mains Road, Edinburgh EH9 3JG, UK

ABSTRACT

The aim of this study was to investigate the relationship between measures of body condition score collected from calving until wk 26 of lactation and reproductive measures (calving interval, days to first heat, days to first service, and conception at first service). Since 1973 sires of cows at the Langhill Dairy Cattle Research Centre have been selected for either high (selection line) or average (control line) genetic merit for fat plus protein. The data included 1211 records from 534 cows calving from 1988 to 1999. At first calving, cows were randomly assigned to one of two ad libitum diets: one that was relatively high in concentrates (~3000 kg/yr) and one that was relatively low in concentrates (~1500 kg/yr). Selection line cows were on average thinner and lost more condition in early lactation than control line cows. Cows that lost condition, those that were thinner than average at wk 10 of lactation and those that were thinner on average over the first 10 wk, had poorer reproductive performance. This effect was greatest in the selection line. Line × diet interaction effects were not statistically significant. Genetic correlations between body condition score and reproductive measures were unfavorable and ranged from $-0.04$ to $-0.54$. The relationship between body condition score and production was strong, but, even after adjusting for yield, an unfavorable relationship still exists between body condition score and fertility. Body condition score could be used as a management and selection tool to improve reproductive performance.

(Key words: fertility, body condition score, energy balance)

INTRODUCTION

Dairy cattle, in common with most lactating mammals, are usually in negative energy balance in the first few weeks of lactation (Berglund and Danell, 1987; Nielsen, 1999). Using genetic correlations between milk yield and DMI, it has been calculated that energy intake of high yielding Holstein cows during this period is less than half the energy requirements for production (Van Arendonk et al., 1991; Veerkamp et al., 1995). As little evidence suggests genetic differences in net efficiency (Veerkamp and Emmans, 1995), the shortfall must be met through mobilization of body tissue; thus, appreciable live weight loss during this time is common (Komaragiri and Erdman, 1997).

Body condition score is used as a subjective method to determine the body reserves of sheep, beef, and dairy cattle (Lowman et al., 1976). The method is based on a visual and tactile appraisal of body fat reserves in the back and pelvic regions and BCS is usually scored on a scale of 1 to 5. The level of fatness or BCS at key periods in a lactation, as well as BCS changes over early lactation, could affect the resumption of estrous cycles and reproductive success. The change in BCS over the first few weeks of lactation may indicate the extent of metabolic load as the shortfall of energy to fuel production is thought to be met through mobilizing body reserves (Pryce and Løvendahl, 1999). Reynolds and Beever (1995) showed that at average production body tissue mobilization supports about 7 kg of milk per day. Loss of BCS has been found to be associated with increased levels of milk production at the phenotypic level (e.g. 5; 28 Waltner et al., 1993), while genetic correlations range between $-0.05$ (Madgwick et al., 1991) in Australia and $-0.46$ in a herd of high yielding Holsteins in the United Kingdom (Veer Kamp, 1998). As genetic merit for production increases, so does mobilization of body reserves. Furthermore, evidence suggests...
that selection for milk yield increases the gap between energy input and output during early lactation (Veerkamp, 1998) because DMI has not been included directly in the breeding goal.

Selection for production has led to a decline in fertility, and published genetic correlation estimates between milk yield and fertility are unfavorable (e.g., Hoekstra et al., 1994; Pryce et al., 1997, 1998). Dairy breeding programs that are centered on production risk leading to cows that are more likely to mobilize body tissue. This may be at the expense of fertility, so it is important to investigate the relationship between energy balance and fertility traits.

Measures of reproductive performance, such as calving interval, days to first service, conception rates etc., have low heritabilities (typically less than 10%: Hoekstra et al., 1994; Pryce et al., 1997, 1998). Furthermore, getting sufficient, reliable data early in the life of a progeny test sire may be difficult. BCS has a heritability of around 0.2 to 0.3 (Jones et al., 1999). If the genetic correlation between BCS and fertility is large enough, then BCS could be useful in a selection index to improve fertility, either by restricting BCS to no genetic change (Jones et al., 1999) or by using BCS as an indirect selection criterion for fertility. Pryce et al. (2000) demonstrated that BCS (adjusted for stage of lactation) has a genetic correlation with calving interval of --0.40.

Data from research herds, such as that at the University of Edinburgh/Scottish Agricultural College Langhill Dairy Cattle Research Centre, complement data collected from national schemes, in that the level of recording in experimental herds is usually much more detailed and may span a longer period. For instance, BCS is measured weekly at Langhill and all estrus and service dates are recorded. These data can be used to investigate the relationship between BCS and far more measures of fertility than are possible with national data. The structure of the Langhill herd also allows the effect of selection for production on body tissue mobilization to be investigated. In 1973, we started a long-term experiment at Langhill to investigate the consequences of selection for genetic merit of fat plus protein by establishing lines that were high and average in the UK for kilograms of fat plus protein. Two different diets were introduced in 1988 to investigate whether or not the advantages of high genetic merit animals are maintained on low input systems (Veerkamp et al., 1995). The experiment was designed so that high and average merit animals on each feeding system were about equally represented. Establishing whether high genetic merit cows differ from their lower genetic merit counterparts in the extent of body tissue mobilization and subsequent effects on fertility is important from economic and animal welfare viewpoints and is also important to inform the design of future breeding programs.

The objectives of this research were: 1) to determine whether or not loss of condition at key periods in a cow’s reproductive cycle affects fertility; 2) to investigate whether the relationship between condition score and fertility were affected by genotype and diet; and 3) to investigate the relationship between BCS measures and fertility on two different diets.

**MATERIALS AND METHODS**

**Data**

Data were obtained on Holstein cows housed and managed at the Langhill Dairy Cattle Research Centre. A total of 1211 records of 534 cows were used for cows calving from the period from September 1988 to January 1999.

The animals were divided into two genetic groups: a selection (S) and a control (C) line. Since the start of the breeding experiment in 1973, the selection criterion for sires of each line has remained the same. Each year four to five AI sires are chosen per line on the basis of their genetic merit for kilogram of fat plus protein (CFP). The S line sires are among the highest available in the United Kingdom and the C line are close to the UK average genetic merit for CFP. Matings are at random, except that matings between close relatives are avoided and bulls known to give a high incidence of calving problems are not used on maiden heifers. The herd replacement rate is currently around 25%. The farm’s policy is to rebreed cows no sooner than 60 d after calving.

Cows are housed from calving (which starts in September each year) until July, and throughout lactation milking is twice daily. While the cows are indoors they are fed complete diets based on grass silage and concentrates. Feeding is ad libitum through Calan Broadbent gates. Since 1988 two feeding regimes have been used, a high concentrate diet (HC) and a low concentrate diet (LC) with S and C animals represented in each feeding system. Each year approximately 40 to 50 heifers enter the experiment; half of each genetic group are assigned to each feeding system. The feeding regimes were designed to achieve the following proportions (in total DM) of concentrates, brewers’ grains, and silage of 20:5:75 (LC) and 45:5:50 (HC). The animals on the HC diet currently have an annual average concentrate intake of about 3000 kg and the LC animals had an average annual intake of about 1500 kg. Higher proportions of concentrates were fed in early lactation, so problems arising from underfeeding in early lactation were minimized. Thus, the proportion of silage in the diet was increased on completion of 100 d and 200 d of lactation.
Cows were scored for condition by the same operator once weekly after the afternoon milking. Condition scoring was on the five-point system (Lowman et al., 1976).

Condition score measures included BCS at wk 1 of lactation (BCS1), BCS at wk 10 of lactation (BCS10), and the change in BCS between wk 1 and wk 10 (BCSCH), and average BCS from wk 1 to 10 of lactation (BCSAVG). The rationale for choosing these measures is that BCS at wk 1 is the first measurement after calving, and so should be less affected by production pressure than BCS measures recorded later in lactation. BCS at wk 10 is around the time of planned insemination at Langhill farm. Furthermore, the greatest change in BCS appears to be from calving to approximately wk 12 (Figure 1).

All reproductive events were recorded and included the dates of the first observed estrous cycle, inseminations, and calvings. Cows not seen in estrus by 56 d postpartum were checked by a veterinarian. The fertility measures calculated included: calving interval (CI), days to first observed heat (DFH), days to first service (DFS), and conception at first service (FSC).

Analysis

The data were analyzed using REML in Genstat 5 (Lawes Agricultural Trust, 1993).

The model fitted was similar to the one used by Pryce et al. (1999), but included a term for proportion of North American Holstein genes, as this is known to affect BCS (Pryce et al., 2000).

\[
Y_{ijklmno} = \mu + a_i + c_i + Yr_j + G_k + Yr_j * G_k + L_l + M_m + F_n + b_1H + e_{ijklmno}
\]

where:
- \(Y_{ijklmno}\) = record with effects as follows,
- \(\mu\) = overall mean,
- \(a_i\) = random effect of cow,
- \(c_i\) = random permanent environmental effect,
- \(Yr_j\) = fixed effect of year of calving,
- \(G_k\) = fixed effect of genetic line (S, C),
- \(L_l\) = fixed effect of lactation number (1, 2, 3, 4+),
- \(M_m\) = fixed effect of month of calving,
- \(F_n\) = fixed effect of diet (HC; LC),
- \(b_1H\) = regression coefficient on percentage North American Holstein genes, and
- \(e_{ijklmno}\) = random error term.

A calving year × genetic line interaction was fitted to account for the effect of the selection line increasing after successive years of selection. Line and feeding system effects and interactions were investigated for the BCS measures only, as they have previously been reported for reproductive measures (Pryce et al., 1999). The relationship between BCS and reproductive measures were investigated by regressing the reproductive measures on the various BCS measures when fitted as an additional covariate to the model written above. Regressions of reproductive measures on BCS within line and diet were also investigated. Preliminary analysis of the data showed that the relationship between BCS and reproductive measures appears to be linear except at the very extremes, so very fat and very thin cows have poorer reproductive performance than cows of intermediate BCS. Few cows fell into the extreme categories; thus, the relationship between BCS and reproductive measures was assumed to be linear. BCS and milk yield are negatively correlated (Veerkamp and Brotherstone, 1997); thus, high yielding cows generally have lower BCS. To account for this and investigate whether a relationship exists between reproductive performance and BCS regardless of milk yield, milk yield averaged over the first 26 wk of lactation was fitted as an additional covariate in the regression analysis of reproductive performance on BCS.

Genetic parameters were estimated using data available before the introduction of the LC diet, i.e., the data were from 1980 to 1999 and comprised 1690 records from 1012 animals. Between 1980 and 1988 all cows were fed the HC diet. The REML program, variance component estimation (Groeneveld and Kovac, 1990), was used to estimate genetic parameters. Genetic correlations were estimated using a series of bivariate animal models. A multivariate model would have been preferable, but was not feasible. A pedigree matrix was fitted that included relatives going back at least two generations. The fixed effects and covariates were the same as in the model fitted for the Genstat analysis.
### RESULTS

Means of the traits are presented in Table 1. BCS was on average 2.63 in the first week after calving, dropping at 2.39 to 10 wk after calving. The average BCS change was −0.28 between wk 1 and 10. In Figure 1, BCS can be seen to be declining steadily until about wk 12.

The average daily milk yield in the first 26 wk of lactation was 28.0 kg for this herd. The CI, DFH, and DFS averaged 396, 47.9, and 77.4 d, respectively. The average conception at first FSC determined by pregnancy diagnosis was 46%. The heritability of milk yield was 0.28, while the heritabilities of reproductive measures were between 0.001 for FSC and 0.18 for DFH. Heritabilities of BCS ranged between 0.09 for BCSCH and 0.36 for BCSAVG.

Line and diet effects of reproductive measures have previously been reported by Pryce et al. (1999), so BCS line and diet means only are presented here. S line cows were of lower BCS at all stages of lactation, and lost more condition from calving to wk 10, than control line cows (Table 2). This was still true after adjusting for the cows phenotypic milk yield (Table 3), although fitting average 26-wk milk yield reduced the difference between the lines and the difference between S and C was no longer statistically significant for BCS1.

Control line cows tended to have similar BCS and BCS change on the two diets, while S line cows tended to have lower BCS and to lose more BCS on the LC diet than on the HC diet. There were no statistically significant line × feeding system interactions.

Regressions of the reproductive measures on BCS demonstrate the effect of a one-point difference in BCS on the reproductive measure concerned. For example, the results in Table 4 show that cows that have BCS one point higher than average at wk 10 of lactation (BCS10), are expected to have a DFH of 5.4 d shorter than average, 14.6 d shorter CI, 6.2 d shorter DFS, a 9% better conception rate (FSC) and 1.9 kg less daily milk. With the exception of DFH, regressions of reproductive measures on BCS1 were not significantly different from zero. Generally a low BCS or average BCS led to poorer reproductive performance. The regression estimate of DFH on BCSCH was −17.4 d (P < 0.001). This means that an increase of one unit of BCSCH would result in a decrease of 17.4 d in DFH. After adjusting BCSCH to the same BCS at wk 10 (BCS10) (BCSCHA) the regression estimate was −18.0 d.

#### Table 1. Means, ranges, standard deviations, heritabilities (h²), and permanent environmental effects (c²) for production, fertility, and BCS.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Mean (SEM)</th>
<th>Min</th>
<th>Max</th>
<th>SD</th>
<th>h² (SEM)</th>
<th>c² (SEM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MY (kg/d)</td>
<td>28.0 (0.1)</td>
<td>10.8</td>
<td>48.3</td>
<td>6.6</td>
<td>0.28 (0.02)</td>
<td>0.41 (0.04)</td>
</tr>
<tr>
<td>DFH (d)</td>
<td>47.9 (0.7)</td>
<td>3</td>
<td>209</td>
<td>27.4</td>
<td>0.18 (0.03)</td>
<td>0.13 (0.02)</td>
</tr>
<tr>
<td>CI (d)</td>
<td>396.0 (1.3)</td>
<td>230</td>
<td>663</td>
<td>48.4</td>
<td>0.01 (0.02)</td>
<td>0.25 (0.03)</td>
</tr>
<tr>
<td>DFS (d)</td>
<td>77.4 (0.5)</td>
<td>55</td>
<td>233</td>
<td>21.3</td>
<td>0.06 (0.02)</td>
<td>0.12 (0.02)</td>
</tr>
<tr>
<td>FSC (0/1)</td>
<td>0.46 (0.02)</td>
<td>0</td>
<td>1</td>
<td>0.50</td>
<td>0.001 (0.001)</td>
<td>0.05 (0.01)</td>
</tr>
<tr>
<td>BCS1 (1 to 5)</td>
<td>2.63 (0.01)</td>
<td>1.25</td>
<td>4.50</td>
<td>0.38</td>
<td>0.28 (0.05)</td>
<td>0.20 (0.04)</td>
</tr>
<tr>
<td>BCS10 (1 to 5)</td>
<td>2.39 (0.01)</td>
<td>0.75</td>
<td>4.25</td>
<td>0.44</td>
<td>0.27 (0.05)</td>
<td>0.28 (0.05)</td>
</tr>
<tr>
<td>BCSCH</td>
<td>−0.28 (0.03)</td>
<td>−1.59</td>
<td>0.68</td>
<td>0.34</td>
<td>0.09 (0.04)</td>
<td>0.10 (0.04)</td>
</tr>
<tr>
<td>BCSAVG</td>
<td>2.53 (0.03)</td>
<td>1.3</td>
<td>3.4</td>
<td>0.37</td>
<td>0.35 (0.05)</td>
<td>0.27 (0.05)</td>
</tr>
</tbody>
</table>

1MY: milk yield averaged over the first 26 wk after calving; DFH: days to first heat; CI: calving interval; DFS: days to first service; FSC: conception at first service; BCS1: BCS at wk 1 after calving; BCS10: BCS at wk 10 after calving; BCSCH: change in BCS from wk 1 to 10; BCSAVG: average BCS from wk 1 to 10 after calving.

#### Table 2. Selection and control line effects for BCS measures.

<table>
<thead>
<tr>
<th>Trait</th>
<th>S</th>
<th>C</th>
<th>SEM</th>
<th>P &lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCS1</td>
<td>2.59</td>
<td>2.63</td>
<td>0.02</td>
<td>*</td>
</tr>
<tr>
<td>BCS10</td>
<td>2.26</td>
<td>2.44</td>
<td>0.02</td>
<td>***</td>
</tr>
<tr>
<td>BCSCH</td>
<td>−0.38</td>
<td>−0.23</td>
<td>0.02</td>
<td>***</td>
</tr>
<tr>
<td>BCSAVG</td>
<td>2.42</td>
<td>2.53</td>
<td>0.02</td>
<td>***</td>
</tr>
</tbody>
</table>

1BCS1: BCS at wk 1 after calving; BCS10: BCS at wk 10 after calving; BCSCH: change in BCS from wk 1 to 10; BCSAVG: average BCS from wk 1 to 10 after calving.

*P < 0.05.

***P < 0.001.

#### Table 3. Line effects for BCS measures estimated after adjustment for average 26-wk milk yield.

<table>
<thead>
<tr>
<th>Trait</th>
<th>S</th>
<th>C</th>
<th>SEM</th>
<th>P &lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCS1</td>
<td>2.59</td>
<td>2.61</td>
<td>0.03</td>
<td>NS</td>
</tr>
<tr>
<td>BCS10</td>
<td>2.29</td>
<td>2.36</td>
<td>0.02</td>
<td>***</td>
</tr>
<tr>
<td>BCSCH</td>
<td>−0.35</td>
<td>−0.29</td>
<td>0.02</td>
<td>***</td>
</tr>
<tr>
<td>BCSAVG</td>
<td>2.43</td>
<td>2.51</td>
<td>0.02</td>
<td>***</td>
</tr>
</tbody>
</table>

1BCS1: BCS at wk 1 after calving; BCS10: BCS at wk 10 after calving; BCSCH: change in BCS from wk 1 to 10; BCSAVG: average BCS from wk 1 to 10 after calving.

***P < 0.001.

NS = Not significant.
BCSCH was adjusted for BCS10 because the impact of losing BCS in early lactation on reproductive performance might be expected to be greater for a cow of low BCS than one with a higher BCS. After adjusting for phenotypic milk yield averaged over the first 26 wk of lactation, the relationship between BCS measures and reproductive measures was generally still unfavorable (Table 5), although the relationship was less strong than when no adjustment for yield was made. The exception was the regression of FSC on BCS1, where the estimate was 0.07 (NS) without adjusting for milk yield and 0.10 ($P < 0.01$) after adjusting for 26-wk milk yield. After adjusting for milk yield, the regression coefficient is significantly different from zero. This can be interpreted as a 10% increase in FSC per unit increase in BCS1 at an average level of milk yield at 26 wk.

Table 5. Regression estimates (SEM) after adjustment for average 26-wk milk yield.¹

<table>
<thead>
<tr>
<th></th>
<th>BCS1</th>
<th>BCS10</th>
<th>BCSCH</th>
<th>BCSAVG</th>
<th>BCSCHA</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFH</td>
<td>6.6</td>
<td>-1.3</td>
<td>-10.2</td>
<td>2.2</td>
<td>-16.9</td>
</tr>
<tr>
<td></td>
<td>(2.4)</td>
<td>(2.1)</td>
<td>(2.1)</td>
<td>(2.3)</td>
<td>(3.3)</td>
</tr>
<tr>
<td>CI</td>
<td>-12.4</td>
<td>-11.9</td>
<td>-5.3</td>
<td>-14.2</td>
<td>-8.1</td>
</tr>
<tr>
<td></td>
<td>(4.5)</td>
<td>(3.9)</td>
<td>(4.0)</td>
<td>(4.5)</td>
<td>(2.5)</td>
</tr>
<tr>
<td>DFS</td>
<td>1.6</td>
<td>-3.9</td>
<td>-5.2</td>
<td>-1.8</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(2.8)</td>
<td>(1.5)</td>
<td>(1.6)</td>
<td>(1.8)</td>
<td>(0.6)</td>
</tr>
<tr>
<td>FSC</td>
<td>0.10</td>
<td>0.06</td>
<td>-0.19</td>
<td>0.10</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.04)</td>
<td>(0.42)</td>
<td>(0.04)</td>
<td>(0.06)</td>
</tr>
</tbody>
</table>

¹MY: milk yield averaged over the first 26 wk after calving; DFH: days to first heat; CI: calving interval; DFS: days to first service; FSC: conception at first service.

P < 0.05.

**P < 0.01.

***P < 0.001.

Differences between regressions of reproductive performance on BCS measures between the two feeding systems were not significantly different from zero, thus BCS or BCSCH had the same effect on fertility in each of the diets.

Genetic relationships between BCS measures and reproductive performance estimated with a series of bivariate analyses are presented in Table 7. All genetic correlations between BCS measures and reproductive performance were unfavorable. Furthermore, the genetic relationships between BCS measures and reproductive performance and between yield traits and reproductive performance are unfavorable. Genetic correlations between BCS and reproductive measures ranged between $-0.04$ and $-0.54$, while genetic correlations between yield traits and reproductive performance ranged from 0.07 to 0.74. These are consistent with the line effects observed by Pryce et al. (1999) who observed significantly longer CI, DFH, and DFS in Langhill S than C line cows. The S line cows had lower BCS measures and a larger (more negative) BCSCH than C line cows (Table 2), which corresponds to the genetic correlations between production and BCS presented in Table 7. However, the lines after phenotypic adjustment for 26-wk milk yield still differ. Genetic correlations between production traits and BCS measures were consistent with the genetic correlations estimated by Veerkamp and Brotherstone (1997). Esti-
Selection for yield of fat plus protein has led to thinner cows that lose BCS in early lactation. Results from a previous study of this herd (Pryce et al., 1999) also showed that S cows have poorer reproductive performance, in that the first heat is delayed, conception rates were poorer, and consequently calving intervals were longer. A strong relationship was found between BCS and reproductive measures. Therefore, to control reproductive performance, managing cattle to predetermined levels of BCS and BCS loss is more important in high than low genetic merit cows. Evidence of a genetic basis to the relationship is presented here. As fertility is diagnosed only after the start of the luteal activity (CLA), as early establishment of ovarian activity is important for fertility. In the present study, start of luteal activity was assessed by observation of estrus behavior by farm staff and recorded as DFH. This measure differs from the genetic level. Thus, thinner cows, or cows in more negative energy balance, tend to have poorer fertility. Butler et al. (1981) also found a negative phenotypic correlation (−0.6) between energy balance in the first 3 wk and days to first ovulation.

Darwash et al. (1997a, 1997b) suggested that progesterone profiles could be used to select for the interval between calving and the start of luteal activity (CLA), as early establishment of ovarian activity is important for fertility. In the present study, start of luteal activity was assessed by observation of estrus behavior by farm staff and recorded as DFH. This measure differs from CLA in that some cows do not show visible signs of estrus in early lactation, even though they are cycling normally. Management emphasis is placed on estrus

### Discussion

One tempting hypothesis is that BCSCH may be more important than condition score recorded on a single occasion, as BCSCH may be more closely related to a change in energy balance. However, our results demonstrate that BCS10 may be better, especially as the heritability of BCS either averaged across early lactation or at wk 10 of lactation, is considerably higher than that of BCSCH. BCS10 is close to the usual start of the service period. The genetic relationship between BCSAVG, BCS10, and fertility was stronger than the relationship between fertility and BCSCH. This indicates that average or absolute BCS (i.e., recorded once rather than a change in BCS) is a potential selection criterion for fertility. In a national data set, where BCS was recorded once in first-lactation animals, the relationship between calving interval and BCS was greatest when BCS measurement was in early lactation (Pryce et al., 2000).

Genetic correlations between BCS and milk yield were high, which is not surprising, as BCS has been argued to be closely related to energy balance and tissue mobilization (Pryce and Løvendahl, 1999). The genetic correlation is, therefore, likely to arise as body tissue is used to fuel some milk production. Nevertheless, as we have shown here, Pryce et al. (2000) and Veerkamp et al. (2000) showed that genetic correlations between energy balance and reproductive measures still exist, even after adjusting for milk yield at the phenotypic and genetic level. Thus, thinner cows, or cows in more negative energy balance, tend to have poorer fertility. Butler et al. (1981) also found a negative phenotypic correlation (−0.6) between energy balance in the first 3 wk and days to first ovulation.

### Table 6
Regression estimates (SEM) of the fertility traits on BCS measures within the two genetic lines.1

<table>
<thead>
<tr>
<th>Measure</th>
<th>BCSCHA</th>
<th>S</th>
<th>C</th>
<th>P (difference)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFH</td>
<td>−21.0</td>
<td>(4.0)</td>
<td>−14.3</td>
<td>(5.4)</td>
</tr>
<tr>
<td>CI</td>
<td>−6.4</td>
<td>(8.0)</td>
<td>3.4</td>
<td>(9.9)</td>
</tr>
<tr>
<td>DFS</td>
<td>−14.3</td>
<td>(3.4)</td>
<td>0.6</td>
<td>(3.5)</td>
</tr>
<tr>
<td>FSC</td>
<td>0.10</td>
<td>(0.06)</td>
<td>−0.04</td>
<td>(0.1)</td>
</tr>
</tbody>
</table>

1DFH: days to first heat; CI: calving interval; DFS: days to first service; FSC: conception at first service; BCSCH: change in BCS from wk 1 to 10; BCS10: BCS at wk 10 after calving; BCSAVG: average BCS from wk 1 to 10 after calving.

### Table 7
Genetic correlations estimated using a series of bivariate analyses.1

<table>
<thead>
<tr>
<th></th>
<th>BCSAVG</th>
<th>BCS10</th>
<th>BCSCH</th>
<th>MY</th>
<th>FY</th>
<th>PY</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI</td>
<td>−0.36</td>
<td>(0.35)</td>
<td>−0.10</td>
<td>(0.26)</td>
<td>−0.04</td>
<td>(0.54)</td>
</tr>
<tr>
<td>DFH</td>
<td>−0.41</td>
<td>(0.12)</td>
<td>−0.49</td>
<td>(0.16)</td>
<td>−0.32</td>
<td>(0.18)</td>
</tr>
<tr>
<td>DFS</td>
<td>−0.54</td>
<td>(0.15)</td>
<td>−0.48</td>
<td>(0.18)</td>
<td>−0.18</td>
<td>(0.24)</td>
</tr>
<tr>
<td>MY</td>
<td>−0.63</td>
<td>(0.10)</td>
<td>−0.59</td>
<td>(0.12)</td>
<td>−0.48</td>
<td>(0.18)</td>
</tr>
<tr>
<td>FY</td>
<td>−0.41</td>
<td>(0.10)</td>
<td>−0.34</td>
<td>(0.11)</td>
<td>−0.17</td>
<td>(0.15)</td>
</tr>
<tr>
<td>PY</td>
<td>−0.54</td>
<td>(0.10)</td>
<td>−0.53</td>
<td>(0.13)</td>
<td>−0.46</td>
<td>(0.18)</td>
</tr>
</tbody>
</table>

1MY: milk yield averaged over the first 26 wk after calving; FY: fat yield averaged over first 26 wk after calving; DFH: days to first heat; CI: calving interval; DFS: days to first service; FSC: conception at first service; BCS10: BCS at wk 10 after calving; BCSCH: change in BCS from wk 1 to 10; BCSAVG: average BCS from wk 1 to 10 after calving.
although these estimates are often based on infrequent
records had to be collected over a number of years.
to have sufficient data to estimate genetic parameters,
correlation cannot be determined. The detail and re-
moves have large standard errors, thus the genetic
is one of the values included in BCSAVG, and because
the BCS measurements were very similar, e.g., BCS10
analysis was found to be unfeasible, because some of
measures reported here and elsewhere. DFH has a
higher heritability than DFS and CI, which could partly
be because DFS and CI are affected by management deci-
sions.
Several studies using data from single research herds
have shown that various BCS measures recorded at
different stages of lactation have moderate heritabil-
ties (0.21 to 0.43) (Koenen and Veerkamp, 1999; Veer-
kamp and Brotherstone, 1997). Similar heritability es-
timates have been reported for nationally recorded BCS
measured at different stages of lactation (0.20 to 0.28;
Jones et al., 1999). These data included single measure-
ments on cows and genetic correlations between stages
of lactation calculated using a sire model. All methods
used in these studies used covariance functions or ran-
dom regression methodology to account for the time
sequence of records. Veerkamp and Thompson (1999)
estimated genetic correlations using bivariate analyses
and multitrait random regression models for milk yield,
DMI, and live weight. Although these methods were
not used in the present study, multitrait covariance
functions could be used to investigate the relationship
between energy balance and fertility. Using random
regression methodology for two traits where one is a
repeated measurement across time and the other is
measured only once would be appropriate. However,
there is a difficulty in that permanent environmental
effects would be calculated for BCS at all stages of
lactation, while only one permanent environmental ef-
fact would be calculated for the single measurement in
a lactation (in this case fertility). Multivariable methods
are likely to be a close approximation of correlations
between BCS and fertility. However, a multivariable
analysis was found to be unfeasible, because some of
the BCS measurements were very similar, e.g., BCS10
is one of the values included in BCSAVG, and because
the data set was relatively small size.
Genetic correlations between BCS and reproductive
measures have large standard errors, thus the genetic
parameters are not accurate and the exact size of the
correlation cannot be determined. The detail and re-
cording accuracy was very high in the present study, but
to have sufficient data to estimate genetic parameters,
records had to be collected over a number of years.
National data sets will provide more robust estimates
of the genetic relationship between BCS and fertility,
although these estimates are often based on infrequent
BCS measurements (e.g., Pryce et al., 2000). The limita-
tion of the Langhill experiment is that for management
reasons, calvings have to be between September and
the beginning of January, thus only the most fertile
cows are represented in this data set. Accounting for
the effect of culling (especially for reproductive failure)
is a major challenge in analyzing dairy cattle fertility
data and ultimately in providing genetic selection tools
for fertility. Nevertheless, this research makes it clear
that BCS has merit as a potential management and
selection tool for improving fertility.

CONCLUSIONS

High genetic merit cows have lower BCS and lose
more body condition in early lactation than do average
merit cows. Loss of BCS in early lactation is unfavor-
ably related to reproductive performance, with the ef-
fect being greater in high genetic merit animals. BCS
recorded once in early lactation is more strongly related
to reproductive performance than change in BCS from
wk 1 to wk 10. BCS is easy to measure and could be
used both for management and in a breeding program
as an indirect selection criterion for fertility.

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