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Relationship between live weight and body condition score in Irish Holstein-Friesian dairy cows

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The objective of this study was to quantify the change in live weight (LWT) per unit change in body condition score (BCS) for Irish Holstein-Friesian dairy cows. Mixed model analyses were performed on 82 948 test-day records of BCS and LWT across 11 075 lactations from 7391 cows, representing 62 commercial and 4 research herds, during the years 1999 and 2000. Factors included in the mixed models were parity, stage of the inter-calving interval and the three-way interaction between herd, year and fortnight of the calendar year at calving. Interactions between the effect of BCS and either parity or stage of the inter-calving interval were included in some models to evaluate the effect of these factors on the relationship between LWT and BCS. A moderate correlation (0.49) existed between BCS and LWT in the complete dataset, but it differed significantly with parity and stage of the inter-calving interval (range 0.36 to 0.59). Analysis of the entire dataset yielded an estimate of 50 kg LWT change per unit change in BCS and this coefficient ranged from 39 kg to 66 kg, depending on parity or the stage of the inter-calving interval. Accurate values of LWT per unit BCS are important input parameters for animal or herd-level biological models designed to evaluate the energy demands of the animal or herd.

Keywords: body condition score; calving interval; live weight; parity

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Introduction

The assessment of body condition score involves visual and tactile appraisal of specific body regions to subjectively assess cow body energy reserves (Wright and Russel 1984). Although sometimes measured on different scales (Roche *et al.* 2004), body condition score (BCS), or change in BCS over time, is used internationally as a tool to aid herd management. Several authors have documented significant phenotypic associations in dairy cows between BCS and health (Gillund *et al.* 2001; Roche and Berry 2006; Berry *et al.* 2007), fertility (Waltner, McNamara and Hillers 1993; Buckley *et al.* 2003; Roche *et al.* 2007) and milk production (Waltner *et al.* 1993; Markusfeld, Gallon and Ezra 1997), thereby substantiating its usefulness as a management aid. Significant genetic correlations of BCS with health (Berry *et al.* 2004), fertility (Pryce, Coffey and Simm 2001; Berry *et al.* 2003) and milk production (Pryce *et al.* 2001; Berry *et al.* 2003) have also been reported.

The rapid catabolism of body tissue in early lactation, followed by slower anabolism towards the end of lactation or in the dry stage is viewed as being energy inefficient (Jarrige 1989). Therefore, interest is growing in the inclusion of BCS in biological models for the energy balance of cows. Furthermore, the inclusion of BCS as a breeding goal trait (Pryce *et al.* 2006) requires the derivation of an economic value for BCS. Body condition score, however, is associated with live weight (LWT), which is commonly used to determine the maintenance requirement of an animal (National Research Council 2001). Despite this association, the relationship between LWT change and BCS change has never been determined for Irish Holstein-Friesian dairy cows.

Previous analyses of data on Holstein-Friesian dairy cows under New Zealand conditions (Berry *et al.* 2006b) revealed that the average change in LWT per unit change in BCS (scale of 1 to 10) was 31 kg. However, significantly different associations were observed across parities and across stages of the inter-calving interval. In Denmark, Enevoldsen and Kirstensen (1997) reported that a change of 1 unit in BCS (scale 1 to 5) was associated with a change of 32 to 47 kg LWT, while Grainger, Wilhems and McGowan (1982) reported a change of 42 kg LWT per unit change in BCS (scale 1 to 8) under Australian conditions.

The objective of the present study was to quantify the LWT change per unit change in BCS under Irish conditions and to investigate if this relationship differed across parities and stages of the inter-calving interval.

Materials and Methods

Data

The data originated from an on-farm study carried out in 1999 and 2000 that involved 75 commercial and 4 research herds in the south of Ireland. Details of the herds and recording procedures were described in more detail by Berry *et al.* (2003) and Buckley *et al.* (2003). In summary, trained personnel visited the farms up to 9 times annually. The interval between visits varied between 2.5 and 4 weeks, with visits being more frequent during early lactation. Live weight and BCS were recorded on all cows in the herd at each visit. Live weight was recorded electronically, using portable weighing scales. The scales were calibrated weekly against a permanently fixed scale at Moorepark Research Centre using cows, and were also checked using known weights on arrival at each farm. Body condition score recorded at weighing was on a scale of 1 (thin) to 5 (fat) in increments of 0.25 (Edmonson *et al.* 1989).

Of the 75 commercial and 4 research herds involved, 66 herds (including the 4 research herds) had at least one record of BCS and LWT on the same date. The data set had 82 948 test-day records, with information on both BCS and LWT, across 11 075 lactations and involving 7391 cows. The inter-calving interval was divided into 6 stages: 64 days pre-calving to 1 day pre-calving, calving to 9 days post-calving, 10 to 50 days post-calving, 51 to 100 days post-calving, 101 to 200 days post-calving and 201 to 300 days post-calving. Parity was coded as 1, 2, 3, 4, 5 or 6+. Fortnight of the calendar year at calving was determined for each lactation, with 1 January as the first day of the first fortnight of the year.

To facilitate a series of separate analyses, LWT was adjusted for the weight of the conceptus (foetus+membranes+fluid) at day *g* of gestation using the formula of Bruce, Broadbent and Topps (1984) and assuming a calf birth weight of 40 kg. Thus,

$$\log_{10} (\text{conceptus weight}) = 2.932 - 3.347e^{-0.00406g}$$

Conception date was estimated as calving date minus 282 (assumed gestation length).

Analysis

Body condition score and LWT were normally distributed. Homogeneity of variance for LWT and BCS across parities and stages of the inter-calving interval was tested using Levene's test (SAS 2006). The correlation between BCS and LWT was estimated, using Proc CORR (SAS 2006), across the complete data set as well as separately within each parity and within each stage of the inter-calving interval. Fisher's *z* transformation was used to derive the confidence interval for each correlation; these transformations were used subsequently to test whether correlations were significantly different from each other.

Mixed model methodology in ASREML (Gilmour *et al.* 2006), with cow included as a random effect, was used to determine the regression of LWT on BCS. Class variables tested in the models were herd, year of calving, fortnight of the year at calving, parity, stage of the inter-calving interval, as well as interactions among all these variables. Body condition score was treated as a continuous variable. Graphical examination of the data revealed a linear association between BCS and LWT and thus only a linear term for BCS was included in the model.

Results

The mean (s.d.) values for BCS and LWT across the entire dataset were 3.01 (0.40) units and 568 (79) kg, respectively. The correlation between BCS and LWT across the entire dataset was 0.49 ($P<0.001$). The corresponding correlation between BCS and LWT adjusted for fetal weight was 0.40. The overall regression coefficient of LWT on BCS was 50 (s.e. 0.37) kg; it declined to 48 (s.e. 0.38) kg when data at calving were excluded. The regression coefficient did not change when the dependent variable was LWT adjusted for fetal weight.

The correlations between BCS and LWT in 1999 and 2000 were similar (0.48 and 0.50, respectively), but yet differed significantly ($P<0.01$).

Parity effects

Mean values of BCS and LWT for each parity, as well as the corresponding estimates for the correlation between BCS and LWT and the regression coefficient of LWT on BCS, are summarised in Table 1. The variation in LWT increased with parity. Nonetheless, Levene's test for homogeneity of variances did not indicate a significant difference among parities. Mean BCS declined from first to second parity but then increased continuously thereafter. The three-way interaction involving herd, year and fortnight of calving was significant for LWT ($P < 0.001$) and was therefore included in the model along with parity and stage of the inter-calving interval, which were also significant sources of variation. Residuals were normally distributed and were randomly scattered when plotted against predicted values.

The correlation between BCS and LWT varied from 0.51 (first parity) to 0.59 (third parity); the correlation in first parity animals was lower ($P < 0.01$) than the correlation for all other parities. Correlations, within parity, between BCS and LWT adjusted for the weight of the conceptus were weaker but followed a similar trend; the weakest correlation (0.36) was for first parity animals and the strongest correlation (0.47) was observed for second and third parity animals.

The regression of LWT on BCS differed significantly ($P < 0.05$) across parities and was lowest for first parity animals. Adjustment of LWT for the weight of the conceptus had minimal effect on the regression coefficients; the regression coefficient of LWT on BCS was 1.26 kg lower following adjustment of LWT for the weight of the conceptus.

Inter-calving interval effects

Results for the effect of stage of the inter-calving interval on mean and variation in LWT and BCS, the correlation between these variables, and the regression of LWT on BCS are presented in Table 2. Mean BCS and LWT were greatest in the pre-calving stage and declined to the mid-lactation stage (days 51 to 100 post-calving) and increased again thereafter. The correlation between BCS and LWT in mid-lactation (0.36) was lower ($P < 0.05$) than that in any other stage, while the correlation for the stage 201 to 300 days post-calving (0.48) was greater ($P < 0.05$) than that for any other stage.

The regression of LWT on BCS differed ($P < 0.05$) among the stages of the inter-calving interval. The regression coefficient was greatest at calving (66 kg) or pre-calving (64 kg) and least in mid- to late-lactation (39 kg). When LWT was adjusted for weight of the conceptus the changes in the regression of LWT on BCS were minimal.

Table 1. The number of records for each parity with the corresponding values for mean and s.d. of live weight (LWT) and body condition score (BCS; scale 1 to 5), the correlation between LWT and BCS and the regression coefficient for LWT on BCS

Parity	Number of records	BCS (units)		LWT (kg)		Correlation between LWT and BCS	Regression of LWT on BCS (kg/unit)
		Mean	s.d.	Mean	s.d.		
1	19066	3.02	0.37	498	60.0	0.51^{a}	44 (0.64)‡
2	19000	2.92	0.38	549	62.4	0.56^{b}	46 (0.63)
3	14920	3.01	0.39	589	65.8	0.59^{c}	52 (0.68)
4	10576	3.05	0.42	613	67.5	$0.58^{c,d}$	55 (0.77)
5	7202	3.06	0.43	621	66.3	$0.56^{b,d}$	53 (0.92)
6+	12184	3.12	0.43	616	68.0	0.56^{b}	55 (0.77)

[a,b,c,d]Correlations without a superscript in common differ significantly ($P < 0.05$).

‡s.e.

Table 2. The number of records for each stage of the inter-calving interval with the corresponding mean and s.d. for live weight (LWT) and body condition score (BCS; scale 1 to 5), the correlation between LWT and BCS and the regression coefficient for LWT on BCS

Stage of inter-calving interval	Number of records	BCS (units)		LWT (kg)		Correlation between LWT and BCS	Regression of LWT on BCS (kg/unit)
		Mean	s.d.	Mean	s.d.		
Pre-calving	16126	3.36	0.36	634	74.8	0.38[b]	64 (0.62)[‡]
Calving	3488	3.14	0.41	564	77.9	0.42[c]	66 (1.04)
Post-calving stage							
10 to 50 days	18252	2.95	0.39	536	70.9	0.39[b,d]	49 (0.54)
51 to 100 days	17552	2.87	0.34	545	69.3	0.36[a]	40 (0.62)
101 to 200 days	22732	2.92	0.34	564	68.2	0.40[c,d]	39 (0.58)
201 to 300 days	4798	3.01	0.38	591	70.5	0.48[e]	50 (1.01)

[a,b,c,d]Correlations without a superscript in common differ significantly ($P < 0.05$).
[‡]s.e.

The inclusion of a term for the three-way interaction between parity, stage of the inter-calving interval and BCS did not significantly increase the proportion of variation accounted for by the model. The regression of LWT on BCS varied from 34 kg (pre-calving stage for parity 4) to 69 kg (10 to 50 days post-calving for parity 2).

Discussion

The change of 50 kg in LWT per unit change in BCS, when estimated across the entire dataset, was considerably less than the change 31 kg LWT per unit change in BCS (scale 1 to 10) reported for Holstein-Friesian dairy cows in New Zealand (Berry *et al.* 2006b) as the change of 31 kg equates to 78 kg LWT per unit BCS when converted to the Irish BCS scale (1 to 5) using the equations from Roche *et al.* (2004). However, the value of 50 kg from the present study agrees well with the range of 32 to 47 kg reported in Danish dairy cattle (Enevoldsen and Kristensen 1997) for a similar BCS scale. Jaurena *et al.* (2005) reported lower values for the regression (21 to 35 kg LWT per unit BCS) in Holstein-Friesian dairy cows. Differences between studies in the relationship between BCS and LWT are expected because LWT is affected by factors such as breed and cow frame size (Stockdale 1999; Enevoldsen and Kristensen 1997); the proportion of North American Holstein-Friesian ancestry in the cows included in the present study was, on average, 48%. Furthermore, the statistical models used differ among studies. For example, the multiple regression model of Enevoldsen and Kristensen (1997) included, among other variables, hip height and hip width, which would be expected to affect the regression of LWT on BCS.

Corroborating the present study, Berry *et al.* (2006b) also reported no significant effect on the correlation between BCS and LWT when LWT was adjusted for weight of the conceptus. The lack of an effect on the correlations between BCS and LWT within parity following adjustment for the conceptus would be expected as the equation applied (Bruce *et al.* 1984) has minimal effect until quite near to calving when only a few records were available.

Parity effects

The finding that mean BCS declined from first to second parity but increased thereafter is consistent with results from most previous studies (Berry *et al.* 2006a; Kertz *et al.* 1997). In agreement with the present study, Berry *et al.* (2006b) also reported significantly different correlations between BCS and LWT across parities for Holstein-Friesian dairy cows in New Zealand. Consistent with the present study, the weakest correlation reported by Berry *et al.* (2006b) was for primiparous cows (0.49) while the strongest (0.63) was for second parity cows; third parity cows (0.58) had the second strongest correlation. One reason for the weaker correlation between BCS and LWT in first parity animals may be that at first calving, animals are only proportionately 0.81 to 0.86 of mature weight (Berry, Horan and Dillon 2005). Since skeletal growth is still on-going in such animals while at the same time body tissue is catabolised in early lactation, the association between LWT and BCS may be affected.

The trend for the regression of LWT on BCS to increase with parity is in agreement with the findings of Berry *et al.* (2006b). The reason for lower LWT per unit BCS in first parity animals may be associated with older animals being larger, affecting the association.

Inter-calving interval effects

In agreement with the present study, Berry *et al.* (2006b) also reported that the correlation between LWT and BCS varied with stage of the inter-calving interval in Holstein-Friesian dairy cows. In that study the strongest correlation (0.59) was for the stage of 10 to 50 days post-calving while the weakest (0.50) was for the stage of 101 to 200 days post-calving. In Irish suckler cows, Drennan and Berry (2006) reported correlations between LWT and BCS that varied from 0.38 at calving in spring to 0.51 in the autumn.

Conclusions

The correlations between BCS and LWT in different parities and stages of lactation are generally within the ranges previously reported in dairy and beef cows. The values reported can be used as input parameters for animal- or herd-level biological models of the energy demand.

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