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Factors Affecting Body Condition Score and Its Relationship with Productive and Reproductive Performances of Holstein Cows

Research Article

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ABSTRACT

The objective of the present study was to determine factors affecting body condition score (BCS) and its association with productive and reproductive performances in Holstein cows. Mixed model analysis was performed on monthly records of BCS from April 2006 to July 2012 comprising 34666 records from 3134 dairy cows in a large commercial dairy herd under arid climatic conditions of Isfahan in Iran. Body condition scores were recorded on a scale of 1 to 5. Fixed factors included in the final mixed model of analysis were evaluation year, parity and evaluation season and also year by parity, season by parity and year by season interaction effects. Average BCS in the dairy herd was 3.06 ± 0.77. The results showed that there was an increasing trend for BCS over the years from 2006 to 2012 ($P<0.001$). Also, the recording season of winter provided greater BCS than other seasons ($P<0.001$). Mean BCS increased from first to third parity but then declined thereafter ($P<0.05$). The correlation between BCS and milk yield was negative and varied from -0.23 to -0.13 over the parities. The correlation between BCS and fat percentage was low and changed from 0 (fourth and greater parities) to 0.08 (first and second parities). There were low to medium correlations (0.14 to 0.29) between BCS and protein percentage over the parities. The correlation estimates between BCS and days open, calving interval and number of inseminations per conception were low and positive, but the correlation between BCS and conception rate was negative over the parities.

KEY WORDS body condition score, dairy cow, production, reproduction.

INTRODUCTION

Negative energy balance in early lactation results in cows to mobilize body tissue in support of lactation. Negative energy balance and excessive body tissue mobilization are associated with increased incidence of metabolic disorders and poor fertility (Loeffler *et al.* 1999; de Vries and Veerkamp, 2000). Among the methods that have been developed to assess the *in vivo* body composition (Chilliard *et al.* 2000), body condition scoring is of particular interest. This method is easy to handle, rather cheap and gives a sufficiently reliable estimation of body energy reserves (Ezanno *et al.* 2003). Moreover, it is well adapted to large-scale surveys with numerous data in an environment where animals are subject to large variations of body fat. Body condition score (BCS) is a management tool used routinely to assess the body fat reserves and energy status in cattle (Edmonson *et al.* 1989). Change in BCS over time reflects both body composition and energy balance, which in turn are critical for metabolic stability (Coffey *et al.* 2001), health (Collard *et al.* 2000) and fertility (Veerkamp *et al.* 2001). The effectiveness of BCS in estimating available energy reserves was outlined by Wright and Russel (1984), who reported a strong positive relationship (r=0.93) between BCS and the proportion of physically dissected fat in Friesian cows. Otto *et al.* (1991) also reported relatively strong correlations (r=0.75) between BCS and the amount of dissected body fat. Despite the effect of energy balance on health and reproduction, until recently, most dairy cattle breeding programs are precisely selected to increase milk production (Miglior *et al.* 2005), without much consideration for traits other than production. This has resulted in a cow that readily mobilizes fat reserves to support lactation (Roche *et al.* 2006), only regaining lost fat reserves when energy expenditure for milk production, maintenance and pregnancy is met. This relationship between BCS and milk production is consistent with fitted functions presented by Roche *et al.* (2006), which accepted body weight and BCS profiles as a mirror for the lactation profile. Energy stores are therefore a key component of milk production.

Several studies have quantified the effect of changes in BCS on dairy cow health throughout the lactation (Markusfeld *et al.* 1997; Roche and Berry, 2006; Berry *et al.* 2007) and reproduction (Domecq *et al.* 1997; Buckley *et al.* 2003; Roche *et al.* 2007b), indicating the importance of these measurable characteristics in dairy farm management. Also, BCS is associated with live weight, which is commonly used to determine the maintenance requirement of an animal (NRC, 2001). Through studies, a general tendency has been arising toward to an improvement in the nonproductive-related traits with increased BCS at calving and through decrease in BCS and body weight in early lactation, although the effect was likely quadratic (Roche *et al.* 2007b). In addition to the effects of genetic selection on BCS (Berry *et al.* 2003; Roche *et al.* 2006), several other environmental factors have also been reported to affect cow BCS, including parity (Pryce *et al.* 2001; Berry *et al.* 2006; Roche *et al.* 2007a), age within parity (Koenen *et al.* 2001; Berry *et al.* 2006) and calving season (Pryce *et al.* 2001). Management (herd-level) factors such as stocking rate (McCarthy *et al.* 2007; Roche *et al.* 2007a; Macdonald *et al.* 2008), feeding level (Roche *et al.* 2006; Roche, 2007b), and diet type (Berry *et al.* 2006; McCarthy *et al.* 2007; Roche *et al.* 2006; Roche *et al.* 2007a) have also been reported to affect cow BCS. The objective of this study was to evaluate the factors affecting BCS of dairy cows and its relationship with production and reproduction traits in Holstein cows.

MATERIALS AND METHODS

Data set

The study was conducted in a large commercial dairy farm in Isfahan, Iran. Monthly records of BCS from April 2006 to July 2012 comprising 34666 records from 3134 dairy cows were included in the data set. Information for individual calving events, including cow identification, 305-d milk yield, 305-d fat and protein percentage, number of inseminations per conception, conception rate, calving date, parity, evaluation date and BCS were included in the data set. BCS were recorded monthly on a scale of 1 (thin) to 5 (fat) (Edmonson *et al.* 1989). Average lactation BCS was derived as the arithmetic means of all BCS over the lactation to correspond with the 305 d adjusted records of productive variables and reproductive traits in this study. The distribution of BCS among dairy cows is shown in Figure 1. In addition, summary statistics for productive and reproductive traits are presented in Table 1. Outliers and defective or doubtful records were deleted from the data set. Months of evaluation (recording) were grouped into four seasons: April through June (season 1=spring), July through September (season 2=summer), October through December (season 3=fall) and January through March (season 4=winter). Days open were considered as the number of days from calving to a successful breeding date and calving interval was defined as the average time interval between successive calvings. The herd used in this study is among the purebred Holsteins that are managed under conditions similar to most other developed countries. The herd is under official performance recording and cows are milked three times a day. Main components of the dairy ration consist of corn silage, alfalfa, cotton seed meal, barley grain, canola meal, wheat bran, fat powder, beet pulp and feed additives. Cows were fed by total mixed ration.

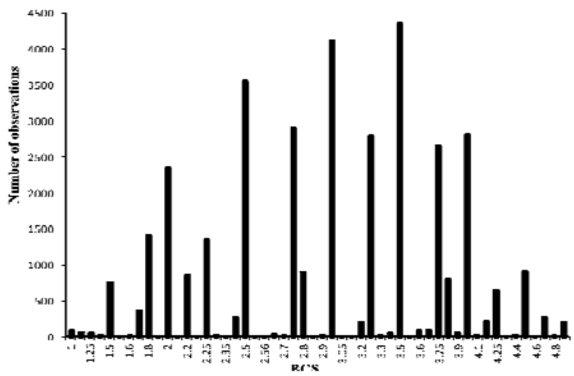

Figure 1 Distribution of body condition scores among dairy cows

Statistical analysis

Statistical analysis of BCS was performed using a linear mixed model (Proc Mixed) with the best fitted covariance structure of SAS (SAS, 2002). The least-squares means were estimated by restricted maximum likelihood (REML) method. Differences among least-squares means were tested using Tukey's adjustment method. The covariance structure used to analyze the BCS of dairy cows was first-order heterogeneous autoregressive structure. Acceptable significant levels were declared at $P < 0.05$. Animal was considered as a random variable in statistical model. The model equation used to analyze BCS was as follows:

$$BCS_{ijklm} = \mu + a_i + Y_j + S_k + P_l + (Y\times P)_{jl} + (S\times P)_{kl} + (Y\times S)_{jk} + e_{ijklm}$$

Where:
BCS_{ijklm}: body condition score observation.
μ: average body condition score in the herd.
a_i: random effect of i^{th} animal.
Y_j: fixed effect of j^{th} evaluation year.
S_k: fixed effect of k^{th} evaluation season.
P_l: fixed effect of l^{th} parity.
Y × P: interaction effect between evaluation year and parity.
S × P: interaction effect between evaluation season and parity.
Y × S: interaction effect between evaluation year and season.
e_{ijklm}: random residual effect.

The correlation between BCS and productive and reproductive traits was estimated using the CORR procedure of SAS (SAS, 2002), separately within each parity. Also, the regression coefficients of productive and reproductive traits on body condition score in Holstein cows were estimated using the REG procedure of SAS (SAS, 2002), separately within each parity.

RESULTS AND DISCUSSION

Average BCS in the dairy herd was 3.06 ± 0.77 and the greatest number of dairy cows had BCS values equal to 3.50 (Figure 1). Effect of different variables on the body condition score of dairy cows is shown in Table 2. The results showed that there was an increasing trend in BCS over the years from 2006 to 2012 (P<0.001). Also, the recording season of winter provided greater BCS than other seasons, but summer and fall seasons had the lowest BCS (P<0.001). There was significant interaction effect between recording year and parity (P<0.05) and cows evaluated in year 2012 and in their third parity had the greatest BCS (3.38). There was significant interaction effect between season and parity and cows evaluated in winter and in their third parity had the greatest BCS (3.24; P<0.05). There was significant interaction effect between recording year and season on BCS and cows evaluated in year 2011 and winter and also in year 2012 and spring had the greatest BCS (3.61; P<0.05). Mean BCS increased from first to third parity but then declined thereafter (P<0.05). Mean BCS was decreased from the first test day to the second one (i.e., nearly 60 days in milk) and increased thereafter through the lactation (Figure 2). Pearson correlation estimates between BSC and productive and reproductive performances, and regression coefficients of productive and reproductive traits on body condition score at different parities in Holstein cows are shown in Tables 3 and 4, respectively. The correlation between BCS and milk yield was negative and varied from -0.23 (second parity) to -0.13 (first and fourth and greater parities). The correlation between BCS and fat percentage was low and changed from 0 (fourth and greater parities) to 0.08 (first and second parities). There were low to medium correlations (0.14 to 0.29) between BCS and protein percentage over the parities. The correlation estimates between BCS and days open, calving interval and number of inseminations per conception were low and positive and varied from 0.03 to 0.18, 0.03 to 0.15 and 0.05 to 0.15, respectively. The correlation between BCS and conception rate was negative and varied from -0.14 (second parity) to -0.05 (fourth and greater parities). Although, the correlations between BCS and fat percentage, days open, calving interval, number of inseminations per conception and conception rate at fourth and greater parities were not significant.

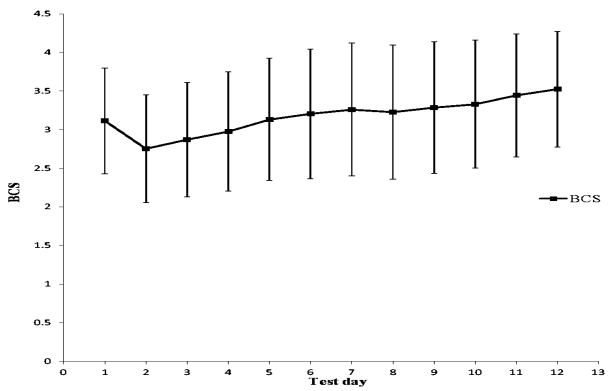

Figure 2 Variation of body condition scores over test days

The regression coefficients of milk yield on BCS varied from -872.46 (parity 2) to -405.52 kg (parity 1); therefore, the milk yield of dairy cows decreased per one unit change in BCS (P<0.05). The regression coefficients of fat percentage on BCS were positive, but only the regression coefficient of fat percentage on BCS was significant, indicating that fat percentage of milk increased per unit change in BCS (P<0.05). The regression coefficients of protein percentage on BCS varied from 0.08 (fourth and greater parities) to 0.17 (parity 3); therefore, the protein percentage of dairy cows increased per one unit change in BCS (P<0.05). The regression coefficients of days open, calving interval, number of inseminations per conception and conception rate on BCS in the first three parities were positive and significant (P<0.05) and changing from 14.55 to 32.52 days, 16.63 to 28.09 days, 0.42 to 0.63 and -0.08 to -0.04%, respectively; but corresponding coefficients were not significant for fourth and greater parities.

Therefore, reproductive performance of dairy cows decreased along with increase in average BCS throughout the lactation.

Table 1 Summary statistics for productive and reproductive traits in dairy cows

Trait	Parity 1		Parity 2		Parity 3		Parity ≥ 4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Milk yield (kg)	11043	1676	11909	2040	12124	2087	11483	2226
Fat percentage	3.20	0.57	3.24	0.56	3.18	0.54	3.15	0.57
Protein percentage	2.61	0.37	2.67	0.35	2.63	0.33	2.58	0.34
Days open (day)	144.7	96.0	150.9	96.5	148.7	90.5	148.8	88.4
Calving interval (day)	419.6	99.1	425.7	99.3	425.2	92.6	424.9	90.1
No. of inseminations	2.83	2.09	3.10	2.23	3.05	2.19	3.06	2.09
Conception rate (%)	55	33	51	32	51	32	51	32

SD: standard deviation.

Table 2 Effect of different variables on the body condition score of Holstein cows

Variable	Class	Number of observations	Body condition score	P-value
Evaluation year	2006	7777	2.91±0.86^{d}	P < 0.001
	2007	4643	2.56±0.85^{e}	
	2008	6392	3.11±0.68^{c}	
	2009	4917	3.21±0.76^{b}	
	2010	5512	3.12±0.67^{c}	
	2011	3119	3.26±0.55^{a}	
	2012	2306	3.26±0.66^{a}	
Evaluation season	Spring	8575	3.03±0.74^{b}	P < 0.001
	Summer	11354	3.01±0.76b^{c}	
	Fall	8214	3.00±0.81^{c}	
	Winter	6523	3.10±0.81^{a}	
Parity	1	12120	2.91±0.72^{d}	P < 0.05
	2	8892	3.08±0.77^{b}	
	3	5868	3.19±0.78^{a}	
	4 ≥	7786	3.05±0.83^{c}	

The means within the same column with at least one common letter, do not have significant difference (P>0.01).

Table 3 Pearson correlation estimates between BSC and productive and reproductive performances in different parities of Holstein cows

Trait	Correlation with BCS			
	Parity 1	Parity 2	Parity 3	Parity ≥ 4
Milk yield	-0.13*	-0.23*	-0.19*	-0.13*
Fat percentage	0.05*	0.05*	0.08*	0.00^{ns}
Protein percentage	0.22*	0.24*	0.29*	0.14*
Days open	0.11*	0.18*	0.09*	0.03^{ns}
Calving interval	0.10*	0.15*	0.10*	0.03^{ns}
No. of inseminations	0.11*	0.15*	0.11*	0.05^{ns}
Conception rate	-0.06*	-0.14*	-0.09*	-0.05^{ns}

* (P<0.05).
NS: non significant.
BCS: body condition score.

Table 4 Regression coefficients of productive and reproductive traits on body condition score in Holstein cows

Trait	Parity							
	1		2		3		≥ 4	
	b_0±SE	b_1±SE	b_0±SE	b_1±SE	b_0±SE	b_1±SE	b_0±SE	b_1±SE
MY	12255±231.9*	-405.52±77.4*	14684±346.6*	-872.46±109.1*	14507±437*	-720.4±134.43*	13109±407.8*	-510.4±128.4*
FP	3.06±0.08*	0.05±0.03^{t}	3.09±0.10*	0.05±0.03^{ns}	2.94±0.12*	0.08±0.04*	3.18±0.11*	0.004±0.04^{ns}
PP	2.19±0.05*	0.14±0.02*	2.20±0.06*	0.15±0.02*	2.09±0.07*	0.17±0.02*	2.35±0.07*	0.08±0.02*
DO	87.24±13.16*	19.12±4.40*	46.73±16.53*	32.52±5.20*	100.30±19.41*	14.55±5.97*	133.52±15.78*	4.03±4.97^{ns}
CI	364.06±13.62*	18.44±4.55*	335.34±17.12*	28.09±5.39*	370.01±19.81*	16.63±6.09*	407.40±16.14*	4.76±5.08^{ns}
INS	1.52±0.28*	0.44±0.10*	1.08±0.39*	0.63±0.12*	1.64±0.46*	0.42±0.14*	2.44±0.37*	0.18±0.12^{ns}
CR	0.65±0.05*	-0.04±0.02*	0.77±0.06*	-0.08±0.02*	0.69±0.07*	-0.05±0.02*	0.60±0.06*	-0.03±0.02^{ns}

MY: milk yield; FP: fat percentage; PP: protein percentage; DO: days open; CI: calving interval; INS: number of inseminations per conception and CR: conception rate.
* (0.05<P<0.10).
NS: non significant.
SE: standard error.

Consistent with our results, other authors reported parity is associated with cow BCS (Dechow *et al.* 2001; Pryce *et al.* 2001; Roche *et al.* 2007a). Berry *et al.* (2011) observed mean BCS of Irish Holstein-Friesian cows declined from first to second parity but then increased continuously thereafter. Ezanno *et al.* (2003) reported body condition of N'Dama cows decreases with parity. Similar to the current results, Ndlovu *et al.* (2009) reported recording month had significant effect on BCS and the peak BCS for Nguni steers was in March. Kadarmideen and Wegmann (2003) showed that cows that were classified in January or February tended to have, on average, smaller BCS than those conditions scored in December. Ezanno *et al.* (2003) reported season is a main factor of BCS variations because it influences BCS in both heifer and adult N'Dama breed but year had not significant effect on BCS. Also, year of calving has been reported as a risk factor for BCS (Pryce *et al.* 2001).

Similar to the current results, loss of BCS has been found to be associated with increased levels of milk production at the phenotypic level (Waltner *et al.* 1993). The changes in BCS over the lactation in this study were consistent with other authors reported the intercalving BCS profile is similar to an inverted milk lactation curve, declining to a nadir at 40 to 100 d after calving (Roche *et al.* 2006; Roche *et al.* 2007a; Sumner and McNamara, 2007) as milk production peaks, before replenishing lost body reserves (Berry *et al.* 2006; Roche *et al.* 2006; Roche *et al.* 2007a; McCarthy *et al.* 2007) as the milk lactation profile declines. Consistent with this mirror image analogy, cows with superior genetics for milk production and, as a result, an elevated lactation profile have a depressed BCS profile (Roche *et al.* 2006; McCarthy *et al.* 2007). Similar to the current results, Berry *et al.* (2011) reported mean BCS was declined from calving to the mid-lactation stage (days 51 to 100 postcalving) and increased again thereafter. Greater postcalving BCS loss increased the height of the lactation profile and the rate of milk yield increase to peak, but reduced lactation persistency. Increasing one factor that contributes to total milk yield (e.g., height of the lactation curve) while decreasing another (e.g., lactation persistency) could potentially result in nonlinear associations between postcalving change in BCS and lactation milk yield (Roche *et al.* 2009). Increased lipolysis provides an energy substrate for non-mammary tissues in early lactation, thereby sparing glucose for mammary lactose synthesis and increasing milk yield (Bauman and Currie, 1980). Therefore, a negative association expected between nadir BCS and milk production. This relationship between BCS and milk production is consistent with fitted functions presented by Roche *et al.* (2006); Roche *et al.* (2007a) and McCarthy *et al.* (2007), who both indicated BCS profiles as mirror images of the milk lactation profile (Roche *et al.* 2009). Garnsworthy and Topps (1982) reported a negative effect of calving BCS on milk yield, with thinner cows producing greater milk yields than fatter cows because of a greater dry matter intake. In most cases, however, milk fat content increased with increasing calving BCS. By comparison, in a review, Stockdale (2001) reported an increase in milk yield and fat content from thin to moderate BCS at calving.

These seemingly contradictory results point to a possible nonlinear association between BCS and milk yield. Results reported in the reviews by Broster and Broster (1998) and Stockdale (2001) propose a curvilinear association between BCS and milk production. Reasons for the inconsistency between the results include the following; 1: an insufficient number of treatments to determine an optimum BCS; 2: selection of treatments that spanned the optimum BCS, thereby resulting in little or no detectable effect of calving BCS on milk production, or that contained too few cows to detect the small effects of BCS change in this range; 3: selection of treatments where the average of the thin cows was, in fact, equivalent to moderate condition and, therefore, close to the optimum for milk production; 4: another reason for the apparent discrepancy between older studies and more recent studies may be the genetics of the animals included in the studies. Breeding programs in dairy cattle have altered the characteristics of the modern dairy cow, which may in turn affect the associations among BCS and performance indicators (Roche *et al.* 2009). Roche *et al.* (2007b) reported protein percentage was negatively associated with postcalving BCS loss. On the other hand, consistent with the current results, Roche *et al.* (2007b) observed fat content increased linearly with increasing BCS. This probably reflects the increased availability of NEFA from greater BCS mobilization, at least in early lactation when the difference is greatest.

A positive relationship was found between average lactation BCS and days open, calving interval, number of inseminations per conception and a negative association was observed between BCS and conception rate in the current study.

Although, there was not a clear reason for the observed relationship between BCS and reproductive performance in this study, but it seems that cows with a high BCS are particularly prone to negative energy balance. Negative energy balance is a frequent condition occurring in high producing dairy cows, such as cows in the current study, some days after calving. It consists of an imbalance between diet energy supply and production requirements. Negative energy balance is the major nutritional factor decreasing reproductive efficiency of high yielding dairy cows, that induces a delay in first ovulation after calving (or a low oocytes quality), an increase in embryo mortality incidence and an increased incidence of uterine diseases with interval from calving to conception that increases over 120-130 days, reduction on conception rate and decrease in pregnancy rate (Rossi *et al.* 2008).

Discrepancies regarding the effects of BCS and body condition change on the reproductive performance of dairy cows are common in the literature. Body condition at parturition has been described as a risk factor (Markusfeld *et al.* 1997), or as having no effect (Waltner *et al.* 1993) on reproductive performance. There is also disagreement in concerning the effect of body condition change on reproductive efficiency. Several authors have noted a linear relationship between postpartum body condition loss and fertility (Domecq *et al.* 1997; Suriyasathaporn *et al.* 1998). Most recent studies suggest a positive association between increased BCS at calving and nadir, reduced postcalving BCS loss (i.e., less extent of negative energy balance), shorter DIM to nadir BCS, and BW gain following the planned start of mating (Buckley *et al.* 2003; Roche *et al.* 2007b) and an earlier attainment of successful pregnancy. Although there is general agreement regarding the importance of energy stores and energy balance on reproduction, there are some inconsistencies in actual relationships.

Some of these inconsistencies may reflect differences in how either BCS (e.g., different scale or time point) or the reproduction variable (e.g., interval fertility trait versus pregnancy or submission trait) is defined, a nonlinear association with BCS at a particular time point on the reproduction variable of interest, which was not fully accounted for in the experimental design or the statistical model, different breeds or genetic strains within breeds, which may also influence mean performance, treatment (e.g., nutritional or hormonal) of animals in the period surrounding the BCS or fertility measures, or the inherent interaction between BCS at different time points (e.g., correlation between BCS at calving and nadir).

CONCLUSION

Average BCS in the dairy herd was 3.06. Recording year and season and parity were significant factors affecting on the BCS of dairy cows. There was an increasing trend for BCS over the years from 2006 to 2012. Also, the recording season of winter provided greater BCS than other seasons. Mean BCS increased from first to third parity but then declined thereafter. Results indicated that loss of BCS has been found to be associated with increased levels of milk production at the phenotypic level. The correlation between BCS and fat percentage was low and positive. Also, there were low to medium correlations between BCS and protein percentage over the parities. Unexpectedly, reproductive performance of dairy cows decreased along with increase in average BCS throughout the lactation. The values reported in the current study can be used as input parameters for animal- or herd-level biological models of the energy demand.

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