Relationship Between Body Condition Scores and Milk Yield in a Large Dairy Herd of High Yielding Holstein Cows[1]

J. J. DOMECQ,[2] A. L. SKIDMORE,[2] J. W. LLOYD,[3] and J. B. KANEENE[3]
Michigan State University, East Lansing 48824

ABSTRACT

This study investigated the relationship between body condition and milk yield of dairy cows. Holstein cows (n = 779) on a commercial dairy farm were scored for body condition weekly beginning at dry-off and continuing until 120 d of lactation. Multiple linear regression and principal component analysis were used to characterize relationships. Mean body condition scores were 2.77 and 2.66 at dry-off and parturition, respectively. Principal component analysis was used to reduce the collinearity among independent variables, to calculate new parameter estimates, and to rank the relationship of each variable with milk yield. Results indicated that change in body condition during the dry period was ranked first, followed by lactation number, and then body condition score at dry-off for multiparous cows. A one-point increase in body condition score between dry-off and parturition was associated with 545.5 kg more milk in the first 120 d of lactation. Each additional point of body condition at dry-off was associated with 300 kg less milk at 120 d of lactation. Results suggested that cows that gained condition during the dry period yielded more milk in the first 120 d of lactation and had an accelerated rate of increase in milk yield. The results of this study indicate that body condition score is an important tool for monitoring dairy herds.
(**Key words**: body condition score, milk yield)

Abbreviation key: **BCS** = body condition score, **DBCS** = BCS at dry-off, **DD** = days dry, **MYA** = milk yield acceleration, **PBCS** = BCS at parturition, **PCA** = principal component analysis.

INTRODUCTION

Body condition scores (**BCS**) are subjective, visual or tactile evaluations of the amount of subcutaneous fat on a cow (1, 8, 31). Two BCS systems for US dairy cattle have been reported in the literature (8, 31). Scores range from 1 (thin) to 5 (obese); scoring increments may be a tenth, quarter, or half points (3). Ferguson et al. (11) clarified and expanded the usefulness of both BCS systems.

Much of the information relating BCS to milk yield is based on studies conducted in the United Kingdom (14). Those studies utilized small numbers of cows, and breeds and management strategies were different from those in the US. Previous studies used a four-point scale, rather than the current five-point scale, to evaluate BCS. These factors make extrapolation of results to conditions in the US difficult. In a review of research from the United Kingdom, Garnsworthy (14) suggested that the relationship between BCS at parturition (**PBCS**) and milk yield was variable and that cows with higher BCS at calving generally lost more body condition during lactation, which could negatively influence milk yield.

Cows that are fat or overconditioned at calving may be at risk for lower yield and increased reproductive and health problems (2, 13, 15, 22). However, the fat or overconditioned cows may represent extremes in BCS that are not typically seen in high yielding dairy herds. Two studies (2, 3) found no difference in health or reproductive problems based on BCS.

Conclusions of more recent studies investigating BCS and milk yield in the US are also variable. Daily milk yields or cumulative milk yields between cows calving above or below a BCS of 3.5 on a five-point scale did not differ in a study involving 66 cows (26). Mean daily milk yield was not influenced by the amount of BCS loss. The amount of BCS loss was related to BCS at calving. Ferguson (10) reported no significant influence of PBCS on milk yield of 1300 cows. Results from Italy (24) indicated that BCS at calving was not important to total milk yield, but a

Received May 3, 1995.
Accepted June 27, 1996.
[1]This research was conducted as part of Regional Research Project NC-119, Dairy Herd Management Strategies for Improved Decision Making and Profitability.
[2]Department of Animal Science.
[3]Population Medicine Center.

change in BCS influenced peak yield and the shape of the lactation curve. In contrast, Waltner et al. (30) suggested that PBCS and a change in BCS during lactation were related to total yield of 3.5% FCM at 90 d of lactation. Ruegg (25) reported no differences in 305-d FCM milk yields or peak milk yield among 429 cows in 13 Canadian herds based on PBCS.

Body condition score at calving appears to have little influence on milk yield. However, changes in BCS, which are related to BCS at calving, have influenced milk yield. The effect of BCS at dry-off (**DBCS**) or changes in BCS during the prepartum period were not included in previous studies and could influence milk yield. The rate of increase in milk yield in early lactation is important to total yield and may more accurately reflect the dynamic biological changes experienced by the cow. The rate of increase in milk yield may be associated with BCS or with changes in BCS.

The goal of this study was to investigate the relationship between BCS and milk yield in high yielding Holstein dairy cows. The research hypothesis tested was that BCS or changes in BCS during the dry period and early lactation are associated with milk yield. Specific objectives were 1) to describe BCS and changes in BCS in the dry period and early lactation, 2) to quantify and rank the associations of BCS and changes in BCS during the dry period and lactation with total milk yield up to 120 d of lactation, and 3) to quantify and rank the associations of BCS with the rate of increase in milk yield between 1 and 15 d of lactation.

MATERIALS AND METHODS

Cow Selection

A commercial dairy farm (1000 cows) located in south central Michigan was used. The herd was housed in a curtain-sided, six-row, free-stall barn; fed a total mixed ration; and milked three times a day. Lactating cows were divided into four groups based on yield and lactation number. First lactation cows were kept in the same group throughout lactation. Dry cows were housed in two groups: an early dry group consisting of cows from dry-off to 3 wk before expected calving and a periparturient group consisting of cows from 3 wk before expected calving to calving.

Cows entered the study at dry-off. All cows that were dried off during 1993 were included. All heifers that calved for the first time between February 15, 1993 and February 15, 1994 entered the study prior to first parturition. Data collection on all cows terminated at 120 d of lactation or when cows were culled from the herd.

BCS

All BCS were assigned by one individual using the visual technique developed by Edmonson et al. (8). Cows were scored to the nearest quarter point. The BCS in this study were validated with ultrasound measurements of subcutaneous fat and were consistent throughout the study (6).

Cows were scored weekly for body condition, and the scorer had no knowledge of the previous BCS. The DBCS was obtained 1 d after dry-off. Each cow was scored weekly through the dry period. The PBCS was determined by using the BCS closest to parturition. The BCS at 30 and 15 d prior to parturition were determined by using the BCS closest to 30 and 15 d prepartum. All BCS obtained during the study were not >3 d from any specific time or event, including parturition or specific days of lactation.

Heifers entered the study when available for prepartum BCS. Typically, heifers were available for BCS 2 to 3 wk before expected parturition. A BCS was assigned weekly during this prepartum period, and a PBCS was determined in the same manner as described for lactating cows. After parturition, cows were assigned a BCS during weekly herd visits.

Milk Yield

Daily milk weights for all cows were electronically stored via a computer located on the farm. The first 120 d of lactation were divided into seven periods to characterize milk yield acceleration (**MYA**) and total milk yield. The MYA represents the rate of milk yield for each period and may more accurately reflect biological changes experienced by the cow during early lactation. There were six 15-d periods beginning at parturition, and the seventh period represented 91 to 120 d of lactation.

For each period, days of lactation was regressed on daily milk yield. The regression coefficient obtained in the analysis was referred to as the MYA and represented the rate of change in milk yield for the respective period. The units for MYA were expressed as kilograms per day squared, and MYA represented the daily increase in milk yield per day of a specific period. The regression coefficients (MYA) were then used to estimate milk yield. Milk yield was estimated for each day in the period, and MYA were obtained for each specific period. The estimated daily milk yields were then combined to obtain total yield for each period. This procedure compensated for missing daily milk weights in the first 120 d of lactation. This procedure also compensated for missing or malfunctioning electronic transponders or for milk weights that were not recorded because cows were missed during milking. Daily milk weights were also missed because cows moved between yield groups, particularly after parturition. Total yield for each period was added to obtain total milk yield at 120 d of lactation. A cow must have had at least five daily milk weights in a period for MYA to be calculated and must have had MYA in each of the seven periods, or the cow was omitted from the analysis.

TABLE 1. Definitions of health disorders.

Disorder	Definition
Dystocia	Assisted delivery
Retained placenta	Retention of fetal membranes >12 h
Metritis	Cloudy discharge and enlarged uterus during rectal exam
Lameness	Any abnormality in locomotion
Displaced abomasum	Pinging sound upon abdominal auscultation and surgical correction
Milk fever	Weakness, cold skin, and favorable response to calcium therapy

Health Disorders

All health disorders were diagnosed and recorded by herd personnel or by the herd veterinarian. The data were collected during weekly visits to the farm. Each health disorder was coded as occurring or not occurring (no = 0; yes = 1). Repeat occurrences or recordings of the same disorder in the same cow were not included. Definitions of health disorders are shown in Table 1 and are similar to those used in previous studies (5, 9, 15). The disorders of interest that were recorded included dystocia, twins, retained placenta, metritis, milk fever, displaced abomasum, and lameness.

Statistical Analysis

BCS and milk yield at 120 d of lactation. The following model for multiple linear regression was developed to test the hypothesis that BCS or changes in BCS during the dry period or early lactation were associated with milk yield: TMY = intercept + DBCS + ΔDBCS + ΔPBCS + LAC + winter + spring + summer + DD + DD^2 + dystocia + twins + RP + MET + DA + MF + lameness + error, where TMY = milk yield at 120 d of lactation; ΔDBCS = change in BCS during the dry period; ΔPBCS = change in BCS from parturition to wk 4 of lactation; LAC = lactation number; winter, spring, and summer = seasons of parturition; DD = number of days dry; RP = retained placenta; MET = metritis; DA = displaced abomasum; and MF = milk fever.

Lactation number was included as a continuous variable in the model because a majority of multiparous cows were in second or third lactation. The mean (±SD) lactation number for multiparous cows was 2.75 (±1.15); 60% of multiparous cows were in second lactation. Milk yield increased linearly between lactations 2 and 3.

Because heifers prior to parturition did not have a BCS equivalent to DBCS (about 60 d prepartum) and because milk yield was different between primiparous and multiparous cows, primiparous cows were analyzed separately with a similar model that did not include the DBCS, ΔDBCS, DD, DD^2, and LAC variables. The PBCS was included in the model for primiparous cows.

Change in BCS during the dry period was determined by subtracting PBCS from DBCS; a negative number indicated an increase in BCS from dry-off to parturition. The change in BCS during the 1st mo of lactation was calculated by subtracting the BCS at wk 4 of lactation from the PBCS; a positive number indicated a decrease in BCS from parturition to wk 4 of lactation.

Calving season was considered to be categorical and was based on the month of parturition. December, January, and February were winter months; March, April, and May were spring months; summer months were June, July, and August; and fall months included September, October, and November. By its omission from the model, fall was the basis for comparison of seasonal effects.

Sire and genetic information was unavailable for >25% of the multiparous cows completing the study. Comparison of frequency distributions of cows with or without sire information indicated differences in several model variables, including milk yield and health disorders. Therefore, no genetic information was included in the model, and the number of cows in the analysis was maximized; results were less biased by cow selection.

Principal component analysis. When any set of independent variables are correlated, the true contribution of each variable to the outcome of interest may not be demonstrated. To avoid this situation, Pearson correlation coefficients and variance inflation factors were calculated between the independent variables of the regression models to detect collinearity.

Principal component analysis (**PCA**) (12, 18, 19, 20, 23) was used to remove collinearity between independent variables in the regression model, to quan-

TABLE 2. Number of cows, means, standard deviations, and ranges of milk yield at 120 d of lactation by lactation.

Lactation	Cows	$\overline{X}$	SD	Minimum	Maximum
	(no.)	(kg)			
1	316	3803	1151	2145	5295
2	275	4918	1498	2272	6289
≥3	188	5205	1540	3095	6805

tify the association of each independent variable, and to rank the variables in order of importance with milk yield.

A decision was made, prior to analysis, to use the principal component vectors that accounted for ≥70% of variation of the correlation matrix of the independent variables from the regression analysis. A vector of new parameter estimates for each independent variable in the original regression model was developed using the methods of O'Brien et al. (23).

The new parameter estimates were multiplied by the standard deviation of the variable to rank the estimates on a standardized scale. A standardized scale was necessary so that comparison and rankings could be made regardless of the unit of measure of the independent variable. The absolute values of the standardized estimates were then ranked; the standardized parameter estimate with the largest contribution to the dependent variable was ranked first. The ranking reflected which of the independent variables had the strongest relationship to the dependent variable after collinearity with other independent variables in the model was reduced.

BCS and MYA. To test the hypothesis that BCS or changes in BCS during the dry period or early lactation were associated with MYA, similar regression models and PCA procedures were utilized. The MYA between 1 and 15 d of lactation was used to represent the rate of increase in milk yield in early lactation. The MYA was used as the dependent variable in the regression models. Principal component analysis was used to reduce collinearity, to quantify the association, and to rank each variable.

RESULTS

A total of 1048 cows entered the study; 141 cows, or 13.5%, were culled or died before 120 d of lactation and were not included in the analysis. The BCS were collected weekly for the 907 cows that completed the study (120 d of lactation). An additional 70 cows were omitted from the analysis because a separate bST study was being conducted. Fifty-eight cows had missing data for yield or other traits and were also omitted, leaving a total of 779 cows in the analysis.

The rolling herd average for 1993 was >10,500 kg of milk. Mean days open was 107, and mean services per conception was 1.8. Bulk tank SCC were consistently <100,000 cell/ml. The mean age at first calving was 24.7 mo. The mean days dry (**DD**) for second lactation was 61.3 (SD = 9.14; range = 16 to 112 d). The third and greater lactation mean for DD was 55.7 (SD = 15.2; range = 9 to 112 d).

Milk Yield

Milk yield at 120 d of lactation and number of cows evaluated by lactation are shown in Table 2. Third and greater lactations were combined into one group. The number of cows in each lactation group was 316, 275, and 188 for first, second, and third and greater lactations, respectively. Mean milk yields by lactation were 3803.2, 4918.2, and 5205.7 kg, respectively; cows in third or greater lactation yielded the highest amount of milk in the first 120 d of lactation. Range of milk yields at 120 d of lactation across all three groups was 2145.3 to 6805.5 kg.

Mean MYA for the first 15 d of lactation are reported in Table 3. The mean rate of increase for first lactation cows was 0.48 kg/d^2. Cows in second and third or greater lactation increased at 0.90 and 0.80 kg/d^2, respectively. The mean coefficients of determination were 0.32, 0.40, and 0.37 for first, second, and third or greater lactation, respectively, indicating that days of lactation explained between 32 and 40% of the variation in daily milk yield during the first 15 d of lactation. The largest MYA for all cows occurred

TABLE 3. Simple regression coefficients (milk yield acceleration) obtained by regressing days of lactation on daily milk yields for the first 15 d of lactation by lactation number.[1]

Lactation	$\overline{X}$	SD
1	0.48	0.63
2	0.90	0.65
≥3	0.80	0.95

[1]Mean coefficients of determination for the regression analysis were 0.32, 0.40, and 0.37 for first, second, and third or greater lactations, respectively.

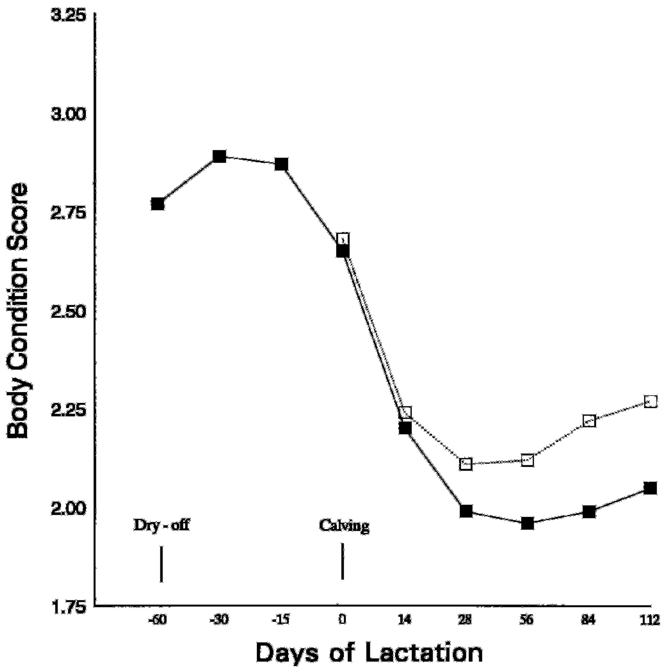

Figure 1. Mean body condition score at specific times during the dry period and lactation for multiparous (■) and primiparous (□) cows.

during the first 15 d of lactation. Daily milk yield did not begin to decrease until 90 d of lactation for first lactation cows but began to decrease after 45 d of lactation for multiparous cows.

BCS

Mean BCS at specific times during the dry period and during lactation for multiparous and primiparous cows in the study are shown in Figure 1. For multiparous cows, mean DBCS was 2.77, and cows gained condition during the early dry period before losing condition during the last 2 wk of the dry period. Mean PBCS was 2.66, which was lower than the DBCS. The lowest BCS occurred between wk 4 and 8 of lactation; mean BCS increased after wk 8 for multiparous cows. Mean loss of BCS in the 1st mo of lactation was 0.62. The pattern of BCS for primiparous cows was similar, but did not drop as low as did the BCS of multiparous cows.

Regression Analysis

Multiparous cows were combined into one group of 463 cows for the regression analysis because of the similarity of milk yield and MYA. The model explained 20% of the variation in milk yield at 120 d of lactation and was significant ($P < 0.0001$). The DBCS, change in BCS during the dry period, change in BCS during the 1st mo of lactation, lactation number, the linear and curvilinear terms for DD, dystocia, lameness, twins, and winter parturition all were significantly associated with milk yield at 120 d of lactation ($P < 0.05$; Table 4).

Parameter estimates indicated that increases in DBCS were associated with lower yield. A curvilinear relationship between DD and milk yield at 120 d of lactation was identified. A PBCS lower than DBCS and loss of condition in the 1st mo of lactation were associated with increased yield. Increasing lactation number was associated with higher milk yield. Dystocia, lameness, and twins were all related to decreased milk yield. Cows calving in winter had increased milk yield compared with cows calving in fall.

The results of the regression analysis of milk yield at 120 d of lactation for the 316 first lactation cows are shown in Table 5. The model explained 8% of the variation in total milk yield and was significant ($P < 0.005$). A change in BCS during the 1st mo of lactation and winter or spring parturition tended to be associated with milk yield at 120 d of lactation ($P < 0.1$). A loss of condition during the 1st mo was related to increased milk yield, and primiparous cows that calved in spring and winter yielded more milk than those that calved in fall.

TABLE 4. Parameter estimates, standard errors, and probabilities of independent variables in multiple regression analysis for multiparous cows on total milk yield at 120 d of lactation.[1]

Variable[2]	Parameter estimate	SE	P
DBCS	–318.72	91.14	0.0005
ΔDBCS	237.19	113.01	0.0364
ΔPBCS	357.06	113.72	0.0018
Lactation number	139.09	27.39	0.0001
DD	42.99	11.73	0.0003
$(DD)^2$	–0.37	0.09	0.0001
Retained placenta	9.39	109.61	0.9317
Metritis	59.38	79.21	0.4539
Dystocia	–272.87	117.89	0.0211
Displaced abomasum	–420.22	457.59	0.3589
Lameness	–630.04	186.61	0.0008
Milk fever	193.97	269.36	0.4718
Twins	–371.68	175.32	0.0346
Parturition			
Winter	398.45	80.19	0.0001
Spring	123.56	97.96	0.2079
Summer	–102.41	85.92	0.2339

[1]Regression model ($P < 0.0001$; $R^2 = 0.2063$; n = 463).

[2]DBCS = Body condition score (BCS) at dry-off, ΔDBCS = change in BCS during the dry period [DBCS – BCS at parturition (PBCS)], ΔPBCS = change in BCS during the 1st mo of lactation (PBCS – BCS at wk 4 of lactation), and DD = days dry.

TABLE 5. Parameter estimates, standard errors, and probabilities of independent variables in multiple regression analysis for primiparous cows on total milk yield at 120 d of lactation.[1]

Variable[2]	Parameter estimate	SE	P
PBCS	65.14	102.86	0.5270
ΔPBCS	172.72	104.60	0.0997
Retained placenta	4.28	121.04	0.9718
Metritis	94.68	75.32	0.1295
Dystocia	–15.32	97.49	0.8752
Displaced abomasum	172.07	180.30	0.3407
Lameness	–400.01	263.12	0.1295
Twins	–96.86	378.97	0.7984
Parturition			
Winter	143.04	82.02	0.0822
Spring	156.63	79.81	0.0506
Summer	–121.10	83.87	0.1498

[1]Regression model ($P < 0.0053$; $R^2 = 0.0826$; n = 316).

[2]PBCS = Body condition score (BCS) at parturition; ΔPBCS = change in BCS during the 1st mo of lactation (BCS at parturition – BCS at wk 4 of lactation).

Regression analysis results for the model investigating MYA for multiparous cows are displayed in Table 6. The model explained 13% of the variation in MYA in the first 15 d of lactation ($P < 0.0001$). The curvilinear term for DD was not statistically associated with MYA ($P > 0.05$) and was not included in the analysis. Summer parturition, DD, metritis, lameness, and parturient paresis approached significance ($P < 0.07$). As DD increased, MYA decreased. Cows that were diagnosed with metritis or milk fever had increased MYA, and lameness was associated with decreased MYA.

The results of the regression analysis of MYA for first lactation cows are shown in Table 7. The model explained 11% of the variation in MYA during the first 15 d of lactation; variation was significant ($P < 0.0001$). The PBCS, change in condition during the 1st mo of lactation, retained placenta, displaced abomasum, and winter and summer calvings all had significant associations with MYA. Winter calvings and an increase in PBCS were related to increased MYA. A loss of condition during the 1st mo of lactation, retained placenta, displaced abomasum, and summer calvings were associated with decreased MYA.

Pearson correlation coefficients for the independent variables in the regression models are shown in the Appendix for multiparous (Table A1) and for primiparous cows (Table A2). Correlations as high as 0.60 were achieved, and many correlations were highly significant ($P < 0.05$), indicating a high degree of collinearity. Variance inflation factors approached 3.0, which also suggested a high degree of collinearity. The parameter estimates and standard errors obtained in the regression analysis may be unreliable because of the high degree of collinearity. The actual, or true, associations of an independent variable may be masked or biased because of an association with other variables in the model.

PCA

Because of the significant associations among independent variables based on Pearson correlation coefficients and variance inflation factors, PCA was used to calculate new estimates. The linear and curvilinear terms of DD were combined into one term for PCA. This combination aided in the interpretation because DD and DD^2 were so highly correlated that a solution with PCA could not be obtained. For these reasons, DD and DD^2 were combined into a single term (NOD) with Equation [1]:

$$NDD = (DD - k)^2. \quad [1]$$

For the current study, k was estimated by solving the first-order conditions of the regular regression equation with respect to DD. Although the regression coefficients employed in this manner were admittedly estimated from data containing substantial collinearity, alternative methods were not found to be superior. The estimate obtained for k (57.78 d) was consistent with both the optimal dry period length of 60 d based on current recommendations (29) and with the mean DD in this herd.

TABLE 6. Parameter estimates, standard errors, and probabilities of independent variables in multiple regression analysis for multiparous cows on milk yield acceleration during the first 15 d of lactation.[1]

Variable[2]	Parameter estimate	SE	P
DBCS	–0.127	0.107	0.2349
ΔDBCS	–0.079	0.132	0.5566
ΔPBCS	–0.133	0.133	0.3204
Lactation number	–0.033	0.031	0.2870
DD	–0.005	0.003	0.0717
Retained placenta	0.083	0.128	0.5187
Metritis	0.185	0.093	0.0457
Dystocia	–0.049	0.138	0.7234
Displaced abomasum	–0.928	0.536	0.0844
Lameness	–0.833	0.218	0.0002
Milk fever	0.571	0.315	0.0712
Twins	–0.198	0.204	0.3332
Parturition			
Winter	0.109	0.093	0.2405
Spring	0.050	0.115	0.6649
Summer	–0.306	0.101	0.0025

[1]Regression model ($P < 0.0001$; $R^2 = 0.1256$; n = 463).

[2]DBCS = Body condition score (BCS) at dry-off, ΔDBCS = change in BCS during the dry period [DBCS – BCS at parturition (PBCS)], ΔPBCS = change in BCS during the 1st mo of lactation (PBCS – BCS at wk 4 of lactation), and DD = days dry.

TABLE 7. Parameter estimates, standard errors, probabilities of independent variables in multiple regression analysis for primiparous cows on milk yield acceleration during the first 15 d of lactation.[1]

Variable[2]	Parameter estimate	SE	*P*
PBCS	0.343	0.122	0.0053
ΔPBCS	–0.339	0.124	0.0069
Retained placenta	–0.245	0.144	0.0894
Metritis	–0.097	0.090	0.2788
Dystocia	0.115	0.116	0.3205
Displaced abomasum	–0.540	0.214	0.0123
Lameness	0.136	0.313	0.6650
Twins	0.158	0.451	0.7268
Parturition			
Winter	0.189	0.099	0.0534
Spring	–0.090	0.095	0.3459
Summer	–0.228	0.100	0.0232

[1]Regression model ($P < 0.0001$; $R^2 = 0.1139$; n = 316).

[2]PBCS = Body condition score (BCS) at parturition; ΔPBCS = change in BCS during the 1st mo of lactation (PBCS – BCS at wk 4 of lactation).

The first eight principal components explained 70% of the variation among the independent variables for multiparous cows, and the first six principal components were needed for primiparous cows.

Table 8 contains the new parameter estimates, standard deviations of each independent variable, and rank of the independent variables for multiparous cows and milk yield at 120 d of lactation. Change in condition during the dry period was ranked first among the independent variables; a one-point increase in PBCS from DBCS was associated with 545 kg more milk in the first 120 d of lactation. Lactation number was ranked second, and each additional lactation was associated with 135 kg more milk. The DBCS was ranked third; an additional point of DBCS was related to 300 kg less milk during the first 120 d of lactation. From Equation [1], the highest milk yield at 120 d of lactation in this herd was observed for 58 DD. A loss of 0.339 kg of milk/d^2 >58 d or <58 d was observed. A cow with 48 or 68 DD yielded 33.9 kg less milk in 120 d of lactation. This DD variable was ranked fourth among the independent variables. A one-point loss of BCS between parturition and wk 4 of lactation was associated with 241 kg more milk in the first 120 d of lactation and was ranked fifth among the independent variables. The variable ranked sixth, winter calving, was associated with 288 kg more milk than was fall calving. Health disorders generally ranked lowest of the independent variables.

Results of PCA of milk yield at 120 d of lactation for primiparous cows are shown in Table 9. The variable ranked first was change in BCS during the 1st mo of lactation. Primiparous cows that lost one point of BCS during the 1st mo of lactation yielded 162 kg more milk than did primiparous cows that did not lose condition. The PBCS ranked second, and increased PBCS was associated with 92 kg more milk. Primiparous cows calving in summer ranked third among independent variables; they yielded 191 kg

TABLE 8. Parameter estimates obtained from principal component analysis, standard deviations,[1] and rank of independent variables for milk yield at 120 d of lactation of multiparous cows.[2]

Variable[3]	Parameter estimate	SD	Rank
ΔDBCS	–545.57	0.47	1
Lactation number	135.07	1.17	2
DBCS	–300.04	0.51	3
$(DD - 57.78)^2$	–0.339	395.73	4
ΔPBCS	242.01	0.40	5
Winter parturition	288.20	0.02	6
Milk fever	1074.10	0.005	7
Lameness	–539.25	0.008	8
Retained placenta	–269.90	0.014	9
Metritis	147.17	0.018	10
Summer parturition	–86.92	0.018	11
Dystocia	–110.80	0.012	12
Displaced abomasum	–442.19	0.003	13
Twins	–103.83	0.008	14
Spring parturition	29.40	0.018	15

[1]Standard deviation for each variable.

[2]Rankings were based on the absolute values of standardized parameter estimates (parameter estimate × SD).

[3]DBCS = Body condition score (BCS) at dry-off, ΔDBCS = change in BCS during the dry period [DBCS – BCS at parturition (PBCS)], ΔPBCS = change in BCS during the 1st mo of lactation (PBCS – BCS at wk 4 of lactation), and DD = days dry.

TABLE 9. Parameter estimates obtained from principal component analysis, standard deviations,[1] and rank of independent variables for milk yield at 120 d of lactation of primiparous cows.[2]

Variable[3]	Parameter estimate	SD	Rank
ΔPBCS	162.77	0.36	1
PBCS	92.43	0.37	2
Parturition			
Summer	–191.59	0.023	3
Spring	104.40	0.025	4
Winter	60.15	0.023	5
Metritis	54.35	0.023	6
Retained placenta	68.45	0.014	7
Lameness	–85.26	0.006	8
Twins	–122.44	0.004	9
Dystocia	17.84	0.018	10
Displaced abomasum	35.50	0.009	11

[1]Standard deviation for each variable.

[2]Rankings were based on the absolute values of standardized parameter estimates (parameter estimate × SD).

[3]PBCS = Body condition score (BCS) at parturition; ΔPBCS = change in BCS during the 1st mo of lactation (PBCS – BCS at wk 4 of lactation).

TABLE 10. Parameter estimates obtained from principal component analysis, standard deviations,[1] and rank of independent variables for MYA of multiparous cows.[2]

Variable[3]	Parameter estimate	SD	Rank
DD	–0.06	12.27	1
DBCS	–0.33	0.51	2
ΔDBCS	–0.32	0.47	3
Lactation number	–0.07	1.17	4
ΔPBCS	–0.06	0.40	5
Parturition			
Summer	–0.36	0.018	6
Spring	0.24	0.018	7
Winter	0.19	0.02	8
Metritis	0.20	0.018	9
Dystocia	–0.09	0.012	10
Retained placenta	0.06	0.014	11
Displaced abomasum	–0.28	0.003	12
Lameness	0.02	0.008	13
Milk fever	0.02	0.005	14
Twins	0.01	0.008	15

[1]Standard deviation for each variable.

[2]Rankings were based on the absolute values of standardized parameter estimates (parameter estimate × SD).

[3]DD = Days dry, DBCS = body condition score (BCS) at dry-off, ΔDBCS = change in BCS during the dry period [DBCS – BCS at parturition (PBCS)], ΔPBCS = change in BCS during the 1st mo of lactation (PBCS – BCS at wk 4 of lactation), and DD = days dry.

less milk than did cows calving in fall. Health disorders generally ranked lowest among independent variables.

The results of PCA for multiparous cows and MYA are shown in Table 10. The DD variable was ranked first; each additional DD was associated with a 0.06-kg/d^2 decrease in MYA. The DBCS ranked second and was related to a decrease of 0.33 kg/d^2 in MYA for every one-point increase in DBCS. Change in BCS during the dry period ranked third. A one-point increase in BCS during the dry period was associated with an increase in MYA of 0.32 kg/d^2.

Measures of body condition for primiparous cows ranked the lowest of the independent variables used to investigate MYA. The rankings and parameter estimates are presented in Table 11. Winter calving ranked first and was associated with an increase in MYA of 0.25 kg/d^2. Retained placenta, displaced abomasum, and summer and spring calving were all related to decreased MYA.

DISCUSSION

MYA

The MYA term was initially developed to investigate the possible effect of the rapid increase in milk yield on conception to first service (7). The hypothesis in that preliminary study (7) was that MYA was associated with reduced conception and may more accurately reflect dynamic biological changes and negative energy balance experienced by the cow during early lactation. An association between MYA and conception was identified, but total milk yield at 120 d of lactation had no association with conception (7). Based on the results of this preliminary study (7), MYA could be an important indicator of cow performance.

As cited in previous studies (14, 25, 26), the association between BCS and milk yield examined rates of milk yield by comparing daily milk yields. This approach might not reflect the rate of increase in yield experienced by a cow. The rate of increase may have a greater influence on the association between BCS and milk yield. In the current study, the largest MYA occurred between 1 and 15 d of lactation for cows in this herd. The correlation between MYA in the first 15 d of lactation and total milk yield at 120 d of lactation was 0.23, which was the highest correlation achieved among the seven MYA and total milk yield.

BCS

Overall mean BCS for cows on the study (Figure 1) suggested that this herd was not achieving current recommendations for BCS at various points during lactation (1, 8, 12, 31). The BCS reported in this study were generally lower than those reported in previous work (12, 25, 26, 30, 31) that investigated the influence of BCS on yield. However, in two previous studies (16, 17) in which cows in different herds

TABLE 11. Parameter estimates obtained from principal component analysis, standard deviations,[1] and rank of independent variables for milk yield acceleration of primiparous cows.[2]

Variable[3]	Parameter estimate	SD	Rank
Winter parturition	0.25	0.023	1
Retained placenta	–0.28	0.014	2
Displaced abomasum	–0.33	0.009	3
Dystocia	0.16	0.018	4
Summer parturition	–0.11	0.023	5
Metritis	–0.09	0.023	6
Spring parturition	–0.08	0.025	7
Twins	0.21	0.004	8
ΔPBCS	–0.002	0.36	9
PBCS	–0.001	0.37	10
Lameness	–0.03	0.006	11

[1]Standard deviation for each variable.

[2]Rankings were based on the absolute values of standardized parameter estimates (parameter estimate × SD).

[3]PBCS = Body condition score (BCS) at parturition; ΔPBCS = change in BCS during the 1st mo of lactation (PBCS – BCS at wk 4 of lactation).

were scored by the same individual as in the current study, BCS were similar at various points of lactation.

There are several possible reasons for the lower BCS of cows in this herd. In general, this herd had higher yield than that reported in some of the previous studies (12, 25, 26, 30, 31), which might suggest an increased demand for energy reserves by high yielding cows. Published information is limited regarding optimal BCS for high yielding dairy cows. The BCS of this commercial herd might have been more typical of high yielding dairy cows milked three times daily. Possibly, a herd could have lower BCS because of poor management, but the high milk yield, excellent reproductive status, and milk quality suggested that high management was maintained in this herd. A comparison of BCS across high yielding herds would be useful.

Recommendations for BCS are that cows maintain BCS between dry-off and parturition (1, 8, 10, 12, 31). Cows in this study gained BCS early in the dry period, but the PBCS was lower than the DBCS because of loss of BCS late in the dry period. The loss of BCS during the late dry period corresponded with the drop in DMI 2 wk before parturition (21, 29) and might have reflected the nutritional status of the cow at this time. Information is limited regarding BCS or changes in BCS during the dry period of high yielding cows.

The mean loss of BCS in early lactation was similar to that of cows from other studies (4, 10, 12, 25, 26, 30). However, during this study, the lowest BCS was reached between the 4th and 8th wk of lactation, which was earlier than in previous studies (10, 12, 30). The milk yield or MYA of cows in this study might have necessitated earlier and more rapid mobilization of energy reserves after parturition. The lower BCS at nadir than previously reported might also suggest that a cow might not have had BCS to lose once the nadir BCS was reached.

Regression Analysis

The models used in the regression analysis were significant predictors of both milk yield and MYA. However, only 8 to 20% of the variation was explained. Milk yield is influenced by many factors that were not considered in this study. Dry matter intake and nutrient densities of rations are examples of variables that affect milk yield, but those factors were not included in the regression models because of the difficulty in field data collection. Genetic merit of a cow also influences milk yield, but genetic merit was not included in this study.

A statistically significant curvilinear relationship was found to exist between DD and milk yield. No other independent variables, including DBCS, had a significant curvilinear association with milk yield. Because no significant curvilinear relationships were identified, curvilinear terms for independent variables were not included in the models before the final regression analysis was performed, which allowed for easier interpretation of results.

The regression analysis of MYA indicated that BCS and changes in BCS were not significantly associated with MYA of multiparous cows. The MYA of multiparous cows was related to DD and disease. Summer calving was significantly related to a decreased MYA for all cows. Because of the collinearity of the independent variables, it is difficult to obtain the true influence of a single variable or to draw any conclusions from traditional regression analysis.

PCA

The results of the PCA clarified the relationship of an independent variable and the dependent variable in the regression model. Using PCA, each independent variable can be considered independently without the correlation or interaction of another variable or variables. Previous research (14, 15, 25, 26) has suggested collinearity among BCS, changes in BCS, and health. Collinearity existed among the independent variables in this study, as indicated by correlation coefficients and variance inflation factors, suggesting the need for PCA. Even though an independent variable might not have had a significant association with the dependent variable, the independent variable was not dropped from the model before PCA, because each variable may or may not contribute to milk yield after collinearity is reduced, which may be important.

For multiparous cows, BCS, changes in BCS during the dry period, and DD were more important than any other variables measured in the herd. The parameter estimate for change in BCS during the dry period changed from 237 in the original regression analysis to –545 after PCA, indicating that a one-point gain in BCS between dry-off and calving was associated with 545 kg more milk in 120 d of lactation. The collinearity among DBCS, change in BCS during the 1st mo of lactation, and other independent variables in the model was reduced with PCA, and a more reliable estimate was determined. Change in BCS during the dry period is highly correlated with DBCS, PBCS, and DD. The length of DD was also negatively associated with milk yield at 120 d of lactation in this study. Short or long DD were associated with lower milk yield.

These results suggest that multiparous cows in this herd should possibly be dried off at a lower BCS, should gain BCS during the dry period, and should have a PBCS higher than DBCS. Cows in this study generally calved with a lower PBCS than DBCS. After gaining BCS during the dry period, cows have BCS to lose to support milk yield in early lactation. Cows that lost one point of BCS during early lactation yielded 242 kg more milk. The negative association of DD and milk yield suggested that cows should not have long or short dry periods, and milk yield at 120 d of lactation was maximal at 58 DD.

Overconditioned cows has been suggested as a problem in several studies (2, 13, 15, 22). The length of the dry period has also been investigated (27, 28, 29), and extremely long or short dry periods have been related to milk yield and health problems. The cows in this study might have been dried off at a low enough DBCS that overconditioning (BCS >4.0) was not a problem. In two studies (1, 2), diets with extra energy density that were fed to cows in the dry period did not influence yield or health. The results of this study suggested that increasing BCS for a short time during the dry period (58 d) could be beneficial. Relatively short dry periods may not allow the cow enough time to gain BCS before parturition.

As expected, displaced abomasum, retained placenta, dystocia, lameness, and twins were associated with less milk yield in 120 d of lactation. However, metritis and milk fever were associated with more milk, which may be associated with a higher genetic merit for milk yield, thus possibly explaining the positive association with yield. The association of an individual health problem with milk yield was not as great as the association of BCS and milk yield for cows in this study.

Total milk yield for primiparous cows was similar to that for multiparous cows. Change in BCS during the 1st mo of lactation had a stronger association with milk yield than did PBCS. First lactation cows that lost more BCS were associated with increased milk yield at 120 d of lactation. Cows that did not lose BCS during early lactation might not have the genetic merit for higher milk yield. Increasing PBCS by one point was associated with an increase in milk yield. Additional energy reserves may be needed to support milk yield. An investigation of BCS in the 60 d prior to first parturition would be useful to determine the effect of gaining condition during this period.

The PCA of MYA for multiparous cows suggested that DD, DBCS, and change in BCS during the dry period had the greatest association with MYA, which was different from the results of the regression analysis. Increasing DBCS by one point was associated with a decrease in MYA of 0.33 kg/d^2, and an increase in BCS during the dry period of one point was related to a 0.30-kg/d^2 increase in MYA. Cows were dried off at lower BCS than recommended, gained BCS during the dry period without detrimental effects on MYA, and, in fact, increased the rate of milk yield in the first 15 d of lactation. We could not find studies relating BCS during the dry period to MYA or a rate of increase in milk yield.

The MYA was associated positively with retained placenta, metritis, lameness, milk fever, and twins and was negatively related to dystocia and displaced abomasum. Most of the diseases ranked near the bottom of the list of independent variables, indicating that other variables were more important. The low incidence of disease in this herd might have contributed to this positive association.

The PCA of MYA for primiparous cows indicated that PBCS and the change in BCS during the 1st mo of lactation were the least associated of model variables. The PBCS and the change in BCS during the 1st mo of lactation had a significant association with MYA. All variables except winter calving, dystocia, and twins had a negative association with the MYA of first lactation cows. Because the MYA of first lactation cows was not as high as that for multiparous cows, the association may not be as strong for BCS and changes in BCS.

Results of this study should be interpreted with caution. This study was conducted for one herd. Future work should be done across herds to see whether the relationships established in this herd would exist for other herds under different management conditions. Both BCS and milk yield reflect the energy status of the cow, which is also related to many factors that were not measured in this study. Total milk yield in the first 120 d of lactation was used, which might not permit consideration of any long-term associations that BCS or health problems might or might not have on milk yield for an entire lactation. Additional work is needed to explain the possible biological mechanisms relating BCS and milk yield. Controlled experiments could determine and identify possible reasons for the results obtained in this observational study.

Based on the results of this study, the hypothesis that BCS or changes in BCS during the dry period or early lactation are associated with milk yield was accepted. An important dairy management tool, BCS can be used to monitor the productivity of dairy cows.

CONCLUSIONS

The BCS and changes in BCS observed in this high yielding commercial dairy herd were typically lower than the BCS recommended and reported in other studies. Regression and PCA indicated that, in this herd, changes in BCS during the dry period, DBCS, the length of the dry period, and change in BCS during the 1st mo of lactation were more strongly associated with milk yield than were health problems. An increase in BCS during the dry period was related to an increase in milk yield and MYA, and an increase in DBCS was associated with a decrease in milk yield and MYA. Because these findings are contrary to current recommendations, further studies are needed in which a broader range of BCS can be used to confirm the results of this study. A dry period length that is <58 d or >58 d was negatively associated with milk yield and MYA. In most cases, health status had less association with milk yield than did changes in BCS. The parameter estimates generated with standard multiple regression were unreliable because of the collinearity among independent variables. Principal component analysis was used to determine more reliable estimates by reducing the effects of collinearity. Dairy consultants and advisors can use analytical techniques such as PCA to determine which management factors have the largest influence on milk yield in order to make better management decisions. Additional investigation of the role of BCS in high yielding cows during the dry period and lactation is needed.

ACKNOWLEDGMENTS

The authors thank the owners and employees of Halbert Dairy Farm for their assistance and Michigan State University Institute of Agricultural Technology Dairy Management students who assisted in weekly data collection.

REFERENCES

1 Boisclar, Y., D. G. Grieve, O. B. Allen, and R. A. Curtis. 1987. Effect of prepartum energy, body condition, and sodium bicarbonate on health and blood metabolites of Holstein cows in early lactation. J. Dairy Sci. 70:2280.

2 Boisclar, Y., D. G. Grieve, J. B. Stowe, O. B. Allen, and G. K. Macleod. 1986. Effect of prepartum energy, body condition, and sodium bicarbonate on production of cows in early lactation. J. Dairy Sci. 69:2636.

3 Braun, R. K., G. A. Donovan, T. Q. Tran, J. K. Shearer, E. L. Bliss, D. W. Webb, D. K. Beede, and B. Harris. 1986. Body condition scoring as a herd management tool. Compend. Contin. Educ. Pract. Vet. 8:F62.

4 Butler, W. R., and R. D. Smith. 1989. Interrelationships between energy balance and postpartum reproductive function in dairy cattle. J. Dairy Sci. 72:767.

5 Curtis, C. R., H. N. Erb, C. J. Sniffen, R. D. Smith, and D. S. Kronfeld. 1985. Path analysis of dry period nutrition, postpartum metabolic and reproductive disorders, and mastitis in Holstein cows. J. Dairy Sci. 68:2347.

6 Domecq, J. J., A. L. Skidmore, J. W. Lloyd, and J. B. Kaneene. 1995. Validation of body condition scoring with ultrasound measurements of dairy cattle. J. Dairy Sci. 78:2308.

7 Domecq, J. J., A. L. Skidmore, F. Ngwerume, and J. B. Kaneene. 1992. The effect of milk-yield-acceleration in early lactation on first service conception. J. Dairy Sci. 75(Suppl. 1): 165.(Abstr.)

8 Edmonson, A. J., I. J. Lean, L. D. Weaver, T. Farver, and G. Webster. 1989. A body condition scoring chart of Holstein dairy cows. J. Dairy Sci. 72:68.

9 Erb, H. N., R. D. Smith, P. A. Oltenacu, C. L. Guard, R. B. Hillman, P. A. Powers, M. C. Smith, and M. E. White. 1985. Path model of reproductive disorders and performance, milk fever, mastitis, milk yield, and culling in Holstein cows. J. Dairy Sci. 68:3337.

10 Ferguson, J. D. 1992. Body condition scoring. Advanced Dairy Cattle Nutr. Sem. Am. Assoc. Bovine Pract. Conf. Minneapolis, MN.

11 Ferguson, J. D., D. T. Galligan, and N. Thomsen. 1994. Principal descriptors of body condition score in Holstein cows. J. Dairy Sci. 77:2695.

12 Ferguson, J. D., and K. A. Otto. 1989. Managing body condition in dairy cows. Page 75 *in* Proc. Cornell Nutr. Conf. Feed Manuf., Syracuse, NY. Cornell Univ., Ithaca, NY.

13 Fronk, T. J., L. H. Schultz, and A. R. Hardie. 1980. Effect of dry period overconditioning on subsequent metabolic disorders and performance of dairy cows. J. Dairy Sci. 63:1080.

14 Garnsworthy, P. C. 1988. The effect of energy reserves at calving on performance of dairy cows. Page 157 *in* Nutrition and Lactation in the Dairy Cow. 1st ed. Butterworths, London, England.

15 Gearhart, M. A., C. R. Curtis, H. N. Erb, R. D. Smith, C. J. Sniffen, L. E. Chase, and M. D. Cooper. 1990. Relationship of changes in condition score to cow health in Holsteins. J. Dairy Sci. 73:3132.

16 Hady, P. J., J. J. Domecq, and J. B. Kaneene. 1994. Frequency and precision of body condition scoring in dairy cattle. J. Dairy Sci. 77:1543.

17 Hady, P. J., J. J. Domecq, and J. B. Kaneene. 1994. A computer based body condition management system. Compend. Contin. Educ. Pract. Vet. 16:1383.

18 Jackson, J. E. 1991. A User's Guide to Principal Components. John Wiley and Sons, Inc., New York, NY.

19 Lafi, S. 1989. Epidemiologic and economic study of repeat breeder syndrome in Michigan dairy cattle. Ph.D. Diss., Michigan State Univ., East Lansing.

20 Lafi, S., and J. B. Kaneene. 1992. An explanation of the use of principal component analysis to detect and correct multicollinearity. Prev. Vet. Med. 13:261.

21 Marquardt, J. P., R. L. Horst, and N. A. Jorgenson. 1977. Effect of parity on dry matter intake at parturition in dairy cattle. J. Dairy Sci. 60:929.

22 Morrow, D. A. 1975. Fat cow syndrome. J. Dairy Sci. 59:1625.

23 O'Brien, D. J., J. W. Lloyd, and J. B. Kaneene. 1992. A principal component analysis of factors critical to participation in veterinary lifelong education programs. J. Vet. Med. Educ. 20:124.

24 Pedron, O., F. Cheli, E. Senatore, D. Baroli, and R. Rizzi. 1993. Effect of body condition score at calving on performance, some blood parameters, and milk fatty acid composition in dairy cows. J. Dairy Sci. 76:2528.

25 Ruegg, P. L. 1994. Body condition scoring in Holstein dairy cows: relationships with production, reproduction, and disease. Page 176 *in* Proc. Am. Assoc. Bovine Pract., Albuquerque, NM. Frontier Printers, Inc., Stillwater, OK

26 Ruegg, P. L., W. J. Goodger, C. A. Holmberg, L. D. Weaver, and E. M. Huffman. 1992. Relation among body condition score, milk production, and serum urea nitrogen and cholesterol concentrations in high-producing Holstein dairy cows in early lactation. Am. J. Vet. Res. 53:5.

27 Schaeffer, L. R., and C. R. Henderson. 1971. Effects of days dry and days open on Holstein milk production. J. Dairy Sci. 55:107.

28 Sorenson, J. T., and C. Enevoldsen. 1991. Effect of dry period length on milk production in subsequent lactation. J. Dairy Sci. 74:1277.
29 Van Saun, R. J. 1991. Dry cow nutrition: the key to improving fresh cow performance. Page 599 *in* Veterinary Clinics of North America: Food Animal Practice. Vol. 7. W. B. Saunders Co., Philadelphia, PA.
30 Waltner, S. S., J. P. McNamara, and J. K. Hillers. 1993. Relationships of body condition score to production variables in high producing Holstein dairy cattle. J. Dairy Sci. 76:3410.
31 Wildman, E. E., G. M. Jones, P. E. Wagner, R. L. Bowman, H. F. Troutt, and T. N. Lesch. 1982. A dairy cow body condition scoring system and its relationship to selected production characteristics. J. Dairy Sci. 65:495.

APPENDIX

TABLE A1. Simple correlation coefficients between independent variables of the regression model for multiparous cows.[1]

	DBCS	ΔDBCS	ΔPBCS	LAC	Winter	Spring	Summer	DD	Dystocia	Twins	RP	MET	DA	MF	Lameness
DBCS	1.00														
ΔDBCS	0.54	1.00													
ΔPBCS	0.24	–0.41	1.00												
LAC	0.10	0.07	0.04	1.00											
Winter	–0.07	–0.02	–0.001	0.05	1.00										
Spring	–0.14	–0.26	–0.16	0.05	–0.28	1.00									
Summer	0.24	0.20	0.04	0.01	–0.29	–0.23	1.00								
DD	0.10	0.07	0.13	–0.07	0.01	–0.12	–0.05	1.00							
Dystocia	–0.07	–0.01	–0.004	0.06	0.07	–0.02	–0.05	–0.005	1.00						
Twins	–0.01	0.10	–0.12	0.04	–0.001	0.003	0.03	–0.14	0.09	1.00					
RP	–0.01	0.06	–0.12	0.08	–0.04	0.13	–0.02	–0.08	0.11	0.30	1.00				
MET	0.04	–0.04	0.05	0.14	0.15	0.09	–0.09	–0.04	0.05	0.09	0.19	1.00			
DA	–0.02	0.04	–0.07	0.01	0.04	–0.03	–0.03	–0.02	–0.02	–0.01	–0.02	–0.03	1.00		
MF	0.09	0.02	0.02	0.11	0.07	–0.05	0.09	–0.05	–0.03	–0.02	–0.04	0.04	0.04	1.00	
Lameness	0.03	0.10	–0.02	0.16	0.08	0.02	–0.05	0.01	0.004	0.09	0.08	0.08	–0.01	–0.02	1.00

[1]DBCS = Body condition score (BCS) at dry-off; ΔDBCS = change in BCS during the dry period; ΔPBCS = change in BCS from parturition to wk 4 of lactation; LAC = lactation number; winter, spring, and summer = seasons of parturition; DD = days dry, RP = retained placenta, MET = metritis, DA = displaced abomasum, and MF = milk fever.

TABLE A2. Simple correlation coefficients between independent variables of the regression model for primiparous cows.[1]

	PBCS	ΔPBCS	Winter	Spring	Summer	Dystocia	Twins	RP	MET	DA	Lameness
PBCS	1.00										
ΔPBCS	0.62	1.00									
Winter	0.07	0.11	1.00								
Spring	–0.17	–0.12	–0.32	1.00							
Summer	0.13	–0.05	–0.26	–0.32	1.00						
Dystocia	–0.08	–0.03	–0.03	0.19	–0.08	1.00					
Twins	–0.04	–0.10	–0.04	0.04	0.06	0.23	1.00				
RP	–0.06	–0.10	–0.04	0.03	–0.07	0.19	0.14	1.00			
MET	–0.007	–0.01	–0.03	0.20	–0.03	0.15	0.16	0.18	1.00		
DA	–0.11	0.006	–0.09	0.19	–0.04	0.0002	–0.01	0.03	0.01	1.00	
Lameness	0.001	–0.08	0.01	0.06	–0.06	–0.08	–0.009	–0.03	0.01	0.15	1.00

[1]PBCS = Body condition score (BCS) at parturition; ΔPBCS = change in BCS from parturition to wk 4 of lactation; winter, spring, and summer = season of parturition, RP = retained placenta, MET = metritis, and DA = displaced abomasum.