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Relationship of Somatic Cell Score with Fertility Measures

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ABSTRACT

Dairy Herd Improvement data from 284,450 cows in 37 states were used to examine the relationship of test-day somatic cell score, herd, calving year, parity, lactation stage, and calving ease score with fertility measures (rate of nonreturn to estrus by 70 d after first service, days to first service, and days open) for US Holsteins and Jerseys. Factors other than somatic cell score were examined to ensure that the estimation of the effect of somatic cell score was independent of other effects. Nonreturn rates were highest during April and May and lowest during June. Parity had a large effect on nonreturn rate, which was 6 to 7% higher for first parity than for sixth parity and later. Effect of lactation stage at first service on nonreturn rate was large; nonreturn rate increased by 8 to 13% from early to late lactation. Effect of calving ease score on nonreturn rate also was large: a 7% decline in nonreturn rate from score 1 to 5. For Holsteins, a small linear regression was found for nonreturn rate on preceding test-day somatic cell score, but this relationship was not significant for Jerseys. The magnitude of the effect of somatic cell score on fertility traits does not warrant postponing first service when somatic cell score is high.
(**Key words:** fertility, nonreturn rate, somatic cell score, calving ease score)

Abbreviation key: D1 = days from calving to first service, **DO** = days open (days from calving to conception), **NRR** = rate of nonreturn to estrus by 70 d after first service.

INTRODUCTION

Mastitis infections have been suggested to affect reproduction negatively. Moore et al. (1991) and Moore and O'Connor (1993) concluded that a coliform mastitis infection, whether early or late in lactation, may negatively affect reproductive function because of gram-negative endotoxin and various cell mediators on endocrine function. Giri et al. (1984) reported that serum $PGF_{2\alpha}$ increased after intramammary infusion of *Escherichia coli* endotoxin, which may negatively impact reproduction. Barker et al. (1998) and Schrick et al. (1999) studied mastitis and reproduction in an experiment station Jersey herd. Barker et al. (1998) found that the number of days from calving to first service (**D1**) was significantly ($P \leq 0.01$) greater for cows with clinical mastitis before first service (94 d) than for all other groups of cows (71 d). Services per conception were significantly ($P \leq 0.01$) greater for cows with clinical mastitis between first service and conception (2.9) than for cows with clinical mastitis before first service (1.6) or for cows with no clinical mastitis or cows with clinical mastitis after confirmed pregnancy (1.7). Days open (**DO**), the days from calving to conception, for cows with clinical mastitis after first service (137 d) was significantly greater ($P \leq 0.01$) than for control cows and those that developed clinical mastitis after confirmed pregnancy (92 d). Schrick et al. (1999) estimated a loss of $32 for cows with mastitis before first service because of additional DO.

The practical importance of mastitis in open cows lies in a possible management decision to delay breeding until clinical symptoms disappear, especially before first service. After experimental challenge with 30 cfu of *E. coli*, bacteria are cleared within 6 d, and cell counts return to normal by about 2 wk (Shuster et al., 1997). However, in two-thirds of the cases, an estrus would occur prior to 2 wk following an infection. If probability of conception is negatively impacted, breeding can be postponed at the next estrus, but desirability of such a postponement depends on the magnitude of the effect on conception rate. An additional consequence of such a relationship is in establishing economic weights for mastitis in selection. Confirmation of an effect on reproduction would justify an increase in the economic weight on mastitis resistance (SCS) because reproduction has no direct economic weight in current selection indexes.

The objective of this study was to determine the magnitude of a possible effect of elevated SCS before first service on rate of nonreturn to estrus by 70 d after first

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service (**NRR**), D1, and DO in DHI Holstein and Jersey populations. Additionally, effect of herd, calving year, month, parity, lactation stage, and calving ease score on NRR, D1, and DO were examined to ensure that effect of SCS was estimated independently.

MATERIALS AND METHODS

Data

Records from Dairy Records Management Systems (Raleigh, NC) that included SCS for the first three test days; service sire, cow, and parentage identification; DIM at first service; and parity were available for 2,739,530 Jersey and Holstein lactations for four calving years (1995 through 1998) from 37 states (none from California). Calving ease score also was available for some Holsteins. Records for analysis were restricted to first services, cows bred between 15 and 365 DIM, DIM < 150 on third test day, daily milk yield between 4.5 and 109 kg, test-day fat and protein percentages between 2.0 and 8.0, and a minimum of two test intervals within the first three test days with reported fat and protein percentages.

To ensure that all cows had the opportunity to have a subsequent insemination, first services after September 1, 1998, were excluded, which resulted in limiting records to those with calving dates from 1995 through August 1998. The first service was determined to be AI by checking service sire identification against information from the National Association of Animal Breeders (Columbia, MO). Although more than one calving was reported for some cows, only the first available lactation was used.

Reproductive performance was evaluated by NRR, D1, and DO. A first breeding was deemed successful if a cow was not reported in estrus or rebred within 70 d. Records with >56 d between last reported test day and first service were excluded. Breedings to virgin heifers and cows that left the herd within 70 d after first service were eliminated. Second breedings within 4 d were excluded. The DO was determined by matching data from Dairy Records Management Systems with information available in the national database of the Animal Improvement Programs Laboratory (Beltsville, MD). Records with DO > 329 were set to 329 d, which represents three standard deviations above mean.

Herds were required to have >9 AI matings yearly so that herds with little information or incomplete reporting of data could be excluded. To eliminate herds that may have primarily reported only successful inseminations, the mean conception rate for the herd was required to be ≤62.5%. Herd mean was calculated from the past 12 monthly herd conception rates calculated by the dairy records processing centers and included all breedings for pregnant and open cows. Non-AI services were eliminated because they were likely to have a breeding date that was derived from a veterinary diagnosis that estimated the stage of the pregnancy. For most non-AI breedings, the exact number of breedings would not be known, which would result in an overestimation of NRR for non-AI bulls.

Analyses

Data for Jerseys and Holsteins were analyzed separately. Because of the large size of the Holstein dataset and computational limitations, two data subsets were created based on the units position of the herd code and analyzed separately. Each subset contained approximately 10% of the original Holstein dataset.

The model used to relate SCS on test day preceding first service to NRR was

$$y_{ijklmno} = h_i + p_j + s_k + m_l + c_m + t_n + b_n SCS_{ijklmno} + e_{ijklmno},$$

where $y_{ijklmno}$ is NRR for cow o in lactation stage k at first service during calendar month l and an interval n between immediately preceding test day and first service after parity j in year m in herd i; h = random herd effect; p = fixed effect of parity (1, 2, . . ., ≥6); s = fixed effect of lactation stage (DIM < 50, 50 through 59, 60 through 69, . . ., 130 through 139, and > 139) at first service; m = fixed effect of calendar month (January, February, . . ., November, December) of first service; c = fixed effect of calving year (1995 through 1998); t = fixed effect of interval between immediately preceding test day and day of first service; b_n = coefficient for regression of NRR on test-day SCS; and e = effect of random residual. A mixed model was fitted using PROC MIXED REML (SAS Institute Inc., 1996). Although NRR is binomial, no attempt to account for nonnormality was made because mean NRR is near the midrange, and tests of significance should not be greatly disturbed. Quadratic regressions on SCS were evaluated but were nonsignificant ($P \geq 0.05$) for NRR and DO. The interval between date of first service and preceding test day was extremely variable. Therefore, six interval classes (<8 d, 8 through 14 d, 15 through 21 d, 22 through 28 d, 29 through 42 d, and 43 through 56 d) were examined separately to determine whether the effect of elevated SCS just before insemination differed from effect of SCS that was measured several weeks before insemination.

The models for D1 and DO were the same as for NRR, except that s was excluded because of its high correlation with D1 and DO, t was excluded because of partial confounding with D1 and DO, regression on SCS was computed across interval classes for date of first

Table 1. Number of cows analyzed by interval between day of preceding test and first service.

Interval (preceding test to first service, d)	Holstein Set 1	Holstein Set 2	Jersey
	(no.)		
1 through 7	18,112	20,549	10,043
8 through 14	19,836	22,448	10,668
15 through 21	21,216	23,665	11,138
22 through 28	21,455	24,230	11,120
29 through 42	19,234	21,682	9,768
43 through 56	7460	8610	3216
Total	107,313	121,184	55,953

service and preceding test day, and quadratic regression on SCS was included.

For Holstein cows with calving ease data, additional analyses of NRR, D1, and DO were conducted to determine the relationships with calving ease score and calf gender. Analysis was similar to that for SCS except for the addition of fixed effects for calving ease score (1, 2, . . ., 5) and calf gender.

RESULTS AND DISCUSSION

The numbers of cows in each of the six interval classes for date of first service and preceding test day are in Table 1 by breed. Maximum numbers were in the 15- through 21-d and 22- through 28-d classes.

Results for linear regressions of NRR on test-day SCS are in Table 2. For both Holstein data subsets, variation from fitting regressions was significant ($P < 0.01$) but small (F values of 4.03 and 3.35). Thus, an effect from elevated SCS on NRR was not clearly demonstrated for Holsteins. No effect was found for Jerseys. Most signs of regressions were negative in both Holstein datasets. The exceptions were positive regressions for the 43- to 56-d interval in set 1 and the 22- to 28-d interval in set 2. In subset 1, the regressions were of similar magnitude for groups through 21 d and 29 to 42 d, and near zero for 22 to 28 d. For subset 2, results were more variable: largest and of comparable size for 0 to 7 d and 8 to 14 d, near zero for interval 22 to 28 d, and intermediate for the other three intervals.

These results are not directly comparable to those of Barker et al. (1998). Whereas those workers recorded actual clinical mastitis throughout lactation, palpated for pregnancy, and determined species causing infections, we used SCS, considered only the interval up to first insemination and employed NRR as the reproductive measure. An elevated SCS gives no information about species of bacteria that may be involved. Barker et al. (1998) reported that services per conception were 2.9 for clinical mastitis subsequent to first service compared with 1.6 for clinical mastitis before first service, indicating that later or chronic infections may be more detrimental that infection in early lactation. Our interest centered on mastitis before insemination because of the possibility of a management decision to delay breeding cows with elevated SCS (i.e., extend the voluntary waiting period). Our results indicate that an elevated SCS within 2 to 3 wk of first insemination is associated with only a small increase in frequency of Holstein cows subsequently returning to service. Because of the relative costs involved, it is probably not profitable to delay insemination based only on an elevated test-day SCS, although an extension of the voluntary waiting period for first insemination in bST herds

Table 2. Coefficients for regression of rate of nonreturn to estrus by 70 d after first service on preceding test-day SCS by interval between day of preceding test and first service.

Interval (preceding test to first service, d)	Holstein Set 1	Holstein Set 2	Jersey
1 through 7	–0.00345	–0.00518	0.00054
8 through 14	–0.00369	–0.00473	–0.00130
15 through 21	–0.00505	–0.00130	–0.00016
22 through 28	–0.00102	0.00010	–0.00132
29 through 42	–0.00464	–0.00205	0.00360
43 through 56	0.00218	–0.00201	0.00127
F-test statistic (6 df)	4.03**	3.35**	0.47

$^{**}P \leq 0.01$.

Table 3. Coefficients for regressions of days from calving to first service (D1) and days open (DO) on preceding test-day SCS.

Dataset	Linear coefficient	Quadratic coefficient
D1		
Jersey	–0.4891	0.05191*
Holstein 1	–0.3658	0.08417**
Holstein 2	–0.2239	0.07178**
DO[1]		
Holstein	0.7178	-0.03436^{NS}

[1]The number of observations having verified days open was 81,692.

*$P \leq 0.05$.

**$P \leq 0.01$.

has been advocated (Luna-Dominguez et al., 2000). Schrick et al. (1999) reported that reproductive losses due to mastitis infections after insemination are greater than those for infections before insemination. We did not examine SCS after insemination because attractive management alternatives are few once insemination has commenced; cows returning to service would likely be rebred regardless of SCS on preceding test day (unless they are designated for future culling). Our results shed no light on relation of elevated SCS and early embryonic death after confirmed pregnancy, which were reported to be a large effect in a herd of Jerseys (Barker et al., 1998; Schrick et al., 1999).

Quadratic regressions of D1 and DO on SCS are in Table 3. The quadratic regression of D1 on SCS was significant for both Holstein subsets and for Jerseys. The quadratic term was positive and the linear term was negative. D1 reflects in part management decisions about when to commence insemination and in part biological factors (such as estrus expression). The equations indicate that D1 is predicted to decline initially as SCS increases, but to increase for higher values of SCS. Barker et al. (1998) had reported D1 was significantly greater for cows with clinical mastitis before first service than for all other cows (93.6 vs 71 d). Our results are in agreement with those of Barker et al. (1998) for both Holsteins and Jerseys.

In contrast, the quadratic regression of DO on SCS was not significant in Holsteins. The linear regression was positive and significant ($P < 0.01$), indicating an increase of 0.5 days open for each unit increase in SCS.

In Table 4 are significance test results for NRR. All effects were significant except: 1) regressions on SCS for Jerseys, 2) sex of calf for calving ease subset analysis for Holsteins, and 3) interval in Jerseys. Differences between the two Holstein subsets were small. Jersey results differed from Holstein primarily in that the regression on SCS was nonsignificant in Jerseys. Results among the three Holstein subsets differed only in that calving year effects were much smaller in the calving ease subset.

Although not the focus of our investigation, results for factors other than SCS in Table 4 are of interest. The results for NRR for the two Holstein subsets and the Jersey set are in general agreement. Judged by *F*-values, the largest effects were for month of first service and parity number, followed by stage of lactation at first service and calving year. Unexpectedly, effect of group based on interval between previous test day and insemination was also significant in Holsteins (*F*-values ranging from 5.36 to 5.55). Means are not shown, but the following summarizes effects of these factors: 1) month of service: maximum NRR of about 56% in April–May for Holsteins (60% in Jerseys), lowest of 48% in June for Holsteins and Jerseys; 2) parity number: maximum of 56 to 57% in first parity for Holsteins (59% for Jerseys), minimum of 50% in ≥6th parities for Holsteins (53% for Jerseys); 3) stage of lactation of first service: maximum of 56% for >139 d in lactation for Holsteins (6.2% for Jerseys), minimum of 47 to 48% at 49 d in lactation for Holsteins (62% for Jerseys); calving year means ranged from 52 to 55% for Holsteins and 55 to 58% for Jerseys.

Perhaps the most surprising result among the above was the sharp drop in the estimated means of NRR for month of first service from May to June observed in all datasets (Figure 1). The cause is uncertain; possible

Table 4. *F*-tests for fixed effects on rate of nonreturn to estrus by 70 d after first service.

		Holstein		
Effect	Jersey	Set 1	Set 2	Calving ease
Parity	16.95**	28.87**	30.88**	34.61**
Stage	13.71**	19.84**	25.49**	22.07**
Month	20.59**	20.75**	29.79**	22.50**
Calving year	4.46**	17.16**	17.09**	8.44**
Interval	1.62	5.38**	5.36**	5.55**
Regressions	0.47	4.03**	3.35**	4.83**
Calving ease	. . .	. . .	. . .	11.46**
Sex of calf	. . .	. . .	. . .	1.21

**$P \leq 0.01$.

Table 5. Estimated means of rate of nonreturn to estrus by 70 d after first service (NRR), days from calving to first service (D1), and days open (DO) for calving ease scores.

Calving ease score	NRR (%)	D1 (d)	DO[1] (d)
1	52.3	84.3	141.1
2	51.5	84.9	144.6
3	49.4	86.2	148.0
4	48.9	86.2	150.2
5	45.5	86.8	155.8

[1]The number of observations having calving ease scores was 81,692.

reasons may be: temperature-humidity, pasturing patterns, or competition for herdsman's attention from cropping activities. No attempt was made to examine this pattern in different geographical regions.

Also in Table 4 were results for the Holstein calving ease data subset. Calving ease score was significantly related to NRR, but sex of calf was not. Means (Table 5) show that there was a decline in NRR from scores 1 to 2 (52%) to 46% for a score of 5. (Estimated means in the calving ease subset were lower than those for data subsets 1 and 2). Weigel and Rekaya (2000) also reported that cows that experienced a difficult calving (score 4 or 5) had lower conception rates than did cows that experienced no calving problems.

In Table 6 are significance tests for D1 and DO. All effects for D1 were significant. Calving ease score and sex of calf were significant in the calving ease subset. For DO, all effects were significant ($P < 0.01$). Effects of parity number, month of first service, calving ease, and sex of calf were greater for DO than for D1. Calving year effect was smaller for DO than for D1.

Means (not shown) show the following patterns for these factors on D1: 1) Month of first service: maximum in June–July of about 89 d for Holsteins (83 for Jerseys), minimum in fall and winter of 82 d for Holsteins (78 for Jerseys); 2) parity number: no consistent pattern; and 3) calving year: very large effects declining from 1995 precipitously to 1998 (this could be an artifact

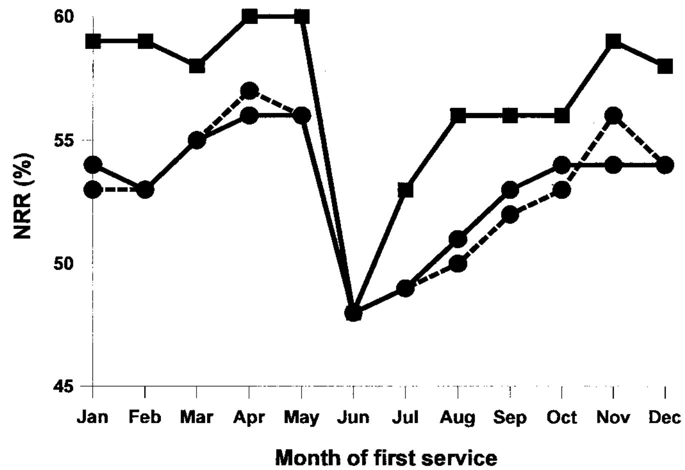

Figure 1. Mean rate of nonreturn to estrus by 70 d after first service (NRR) by month of first service for Holsteins (●) [dataset 1 (——); dataset 2 (– – –)], and Jerseys (■).

due to the truncation manner in which the data were selected for the analysis, both beginning and ending).

Means for DO showed the following: 1) month of first service: maximum was for first services in June (165 d), lowest for October (135 d); 2) parity number: maximum for ≥6th parities (156 d), lowest for first parity (142 d); 3) calving year: maximum in 1998 (159 d), lowest in 1996 (141 d).

In Table 5 are estimated means for calving ease score from the mixed model analysis of NRR, D1, and DO. There was a decline in NRR for successively increasing calving ease scores, from 52% for scores 1 and 2 to 46% for score 5. D1 increased with successive scores, from 84 d for score 1 to 87 d for score 5. Sex of calf (not shown) was not significant for NRR; for D1, estimated means were 85.9 d for cows that had male calves and 85.5 d for those having females. The DO also increased with successive calving ease scores: 141 d for score 1 to 156 d for score 5. For cows having male calves, DO was 149 d, compared with 147 d for those having females.

Table 6. F-tests for fixed effects on days from calving to first service (D1) and days open (DO).

	D1				
		Holstein			
Effect	Jersey	Set 1	Set 2	Calving ease	DO (Holstein)
Parity	15.05**	10.49**	2.65*	4.35*	29.30**
Month	30.42**	68.46**	87.92**	93.82**	101.51**
Calving year	212.48**	434.15**	403.06**	254.11**	211.44**
Calving ease	. . .	. . .	. . .	15.75**	25.46**
Sex of calf	. . .	. . .	. . .	7.04**	17.28**

*$P \leq 0.05$.
**$P \leq 0.01$.

Table 7. Variation in rate of nonreturn to estrus by 70 d after first service (NRR) due to effect of herd.

Dataset	Herds	NRR variation due to herd effect
	(no.)	(%)
Jersey	2113	3.6
Holstein 1	1758	4.1
Holstein 2	1882	3.8
Holstein (calving ease)	2716	3.9

An increase in calving ease score from 1 to 5 (more difficult calving) was associated with a 2.5 d increase in D1. This effect is much smaller than reported by other workers on days to first service. Days to first service increased by 9.3 d from a score of 1 to a score of 4 or 5 in second- and later parity cows (Thompson et al., 1983). Mangurkar et al. (1984) found an increase of 7 d from an unassisted/live calving to surgical/live calving. In other studies, large effects of calving ease score on days open were reported (Djemali et al., 1987; Dematawewa and Berger, 1987; Thompson et al., 1983). While D1 is not perfectly correlated with days open, our data may not fully reflect variation in D1 due to the way in which data were selected for determination and analysis of NRR.

Table 7 gives the percent variation in NRR due to herds. In Holsteins and Jerseys, the percent was 3.6 to 4.1. The small variation due to herds suggests that a mixed model analysis would differ little from a least-squares intraherd analysis. In a previous study, herd-month accounted for 4.3 to 8.8% of variation in 60- and 90-d NRR depending upon geographical area and method of analysis (Weigel and Rekaya, 2000).

SUMMARY AND CONCLUSIONS

Our primary objective was to determine whether elevated SCS before first insemination is negatively related to NRR. No significant relation was found in Jerseys. In two Holstein subsets, significant but relatively small linear regressions of NRR on preceding test-day SCS were found, particularly for SCS recorded within 2 to 3 wk before insemination. However, the magnitude of these regressions (–0.004 to –0.005) seems insufficient to warrant postponing breeding a cow in estrus solely on grounds of a high SCS on previous test day.

Large effects for calendar month of first service were found—maximum in April to May, minimum in June (decline of 12% in Jerseys, 8 to 9% in Holsteins). Parity number also had large effects on NRR, with an increase of 6 to 7% from first parity to sixth and later. Effect of stage of lactation at first service was large, with NRR rising 8 to 13% from early to late lactation. In a subset of data with calving ease information, calving ease score had a significant effect on NRR, with a decline of 7% from score 1 to score 5.

Similar analyses were conducted for D1 and DO. Regression of D1 on SCS was significant and quadratic in both Holsteins and Jerseys. Regression of DO on SCS was significant in Holsteins.

Although results do not suggest postponing first service due to elevated test-day SCS, additional emphasis on mastitis control and a slight increase in the economic weight for SCS in genetic selection is warranted.

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