Effect of Somatic Cell Count on Milk Yield in Different Parities and Stages of Lactation in Holstein Cows of Iran

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Summary

The objective of this study was to investigate the relationship between somatic cell score (SCS) and milk yield in different stages of lactation for cows in different parities. Records between June 2003 and January 2014 from 209,781 cows in lactations one to nine in 845 herds, comprising 2,500,407 monthly test-day (TD) records extracted from the animal breeding center, were used. The MIXED procedure of SAS software was used to investigate the effect of SCS on milk yield in different stages of lactation. Defined model considered herd, year-season of calving, month of TD, weeks in lactation and previous dry period length as fixed effects and calving age and SCS as covariate. Lactations were divided into six stages and analyses were performed within each stage. Also, different lactations were analyzed separately. The amount of daily milk yield loss associated with increased SCS was higher with increased number of parity and also later in lactation (especially after peak in week nine). The regression coefficient for milk yield on SCS was -0.539 to -0.635 in different stages of lactation in first parity cows, while that was between -0.777 to -1.053 in third lactation cows.

Key words

somatic cell score, calving age, dry period length, regression coefficient, stage of lactation

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Introduction

Dairy cattle breeding policies are mainly focused on milk production traits in Iran. Although these traits are of primary economic importance, functional traits such as udder health and productive life are of greater interest to producers to improve the herd profitability. Mastitis is one of the major diseases in dairy cows and leads to economic losses, mainly arising from discarded milk, reduced milk production and quality, and increased health care costs in dairy cows (Wellenberg et al., 2002). Selecting for increased resistance to mastitis can be done directly or indirectly. Direct selection needs the diagnosis of the infection and indirect selection corresponds to use of indicator traits or criterion related to mastitis. Among the measures, the most frequently used to detect mastitis are milk somatic cell count (SCC) (Shook and Schutz, 1993; Mrode and Swanson, 1996) and had been used to estimate the reduction in milk yield associated with mastitis (Ali and Shook, 1980; Raubertas and Shook, 1982; Rajčevič et al., 2003).

A good estimate of milk yield reduction due to increase in SCC can be an incentive for breeding specialists to consider the detrimental effect of disease and to establish appropriate selection programs with balanced weights for mastitis. With some exceptions (Dürr et al., 2008; Hagnestam-Nielsen et al., 2009), most estimates of milk yield losses associated with SCS have been derived from lactation averages. Miller et al. (2004) reported a decrease in 305-day milk yield of 54.6 kg and 61.4 kg per somatic cell score unit increase on the first test-day for the first and second parities, respectively. In a review by Hortet and Seegers (1998), the estimated lactation milk loss was found to vary between 0 and 9.5% across parities for cows developing clinical mastitis. The amount of milk losses associated with mastitis is depended on when in lactation the cow is diseased (Lucey et al., 1986; Rajala-Schultz et al., 1999; Hagnestam et al., 2007). Since mastitis and SCS are highly correlated, in order to obtain accurate estimates stage of lactation should be taken into consideration when studying association between milk yield and SCS. Therefore, the objective of this study was to investigate the relationship between somatic cell count and milk yield per parity and stage of lactation in Holstein cows of Iran.

Material and methods

Records between June 2003 and January 2014 from 209,781 cows in lactation one to nine in 845 herds, comprising 2,500,407 monthly test-day (TD) records extracted from the animal breeding center of Iran, Karaj, were included in dataset. Cows were kept in intensive production systems and fed manually throughout the year with alfalfa hay, corn silage and wheat straw as forages and a mixture of barley grain, corn grain, soybean meal, whole cottonseed, cottonseed meal, canola meal, wheat bran, corn gluten and beet pulp and vitamin and mineral premix as concentrate. In most of herds, cows were housed in covered barns with concrete floors and free stalls and, in herds with medium to large sizes, were grouped regarding to the stage of lactation, production and pregnancy status.

The dataset file included animal ID, herd, calving date, parity, calving age, test-day milk and somatic cell count, test-dates, and dates of drying off. Records between days 5 to 305 DIM were included. Daily milk yields less than 8 kg were deleted, because these represent a recording error or a sick cow. Only animals with five or more test-day records were included. Somatic cell count was transformed to SCS. Number and percent of data in different SCS classes in different lactations are shown in Table 1. Calving age was calculated as a date of calving minus date of birth. Also, dry period length was calculated as the date of present calving subtracted from date of pervious dry off. Months of calving 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). Only herds with three milking times per 24 h were included. According to a study by Hagnestam-Nielsen et al. (2009) that reported dividing lactation to six stages resulted in better model fit, lactations were divided into six stages (wk 1 to 2, 3 to 8, 9 to 16, 17 to 24, 25 to 32, and 33 to 44) and analyses were performed within each stage. Also, dry period length of cows was grouped into 14 classes: 0-10 (class 1), 11-20 (class 2), 21-30 (class 3), 31-40 (class 4), 41-50 (class 5), 51-60 (class 6), 61-70 (class 7), 71-80 (class 8), 81-90 (class 9), 91-100 (class 10), 101-110 (class 11), 111-120 (class 12), 121-130 (class 13) and > 130 (class 14). Weeks in lactation were divided into 19 classes (records collected within the first 8 weeks of lactation were grouped into weekly intervals, records from week 9 to 16 were grouped into 2-weeks periods, and records taken later than 17 weeks after calving were grouped into 4-weeks periods). The MIXED procedure of SAS software (SAS Inst., 2002) was used to investigate the effect of SCS on milk yield in different stages of lactation with the following model:

Table 1. Number (percent) of test-day records in different SCS's class in different lactations

SCS[a]	1st lactation	2nd lactation	3rd lactation	≥4th lactation
0	122204 (13.72)	54296 (9.12)	28769 (6.84)	28782 (5.15)
1	237273 (26.64)	101878 (17.11)	57474 (13.66)	59219 (10.60)
2	201557 (22.63)	119835 (20.12)	74075 (17.61)	80944 (14.49)
3	126847 (14.24)	105400 (17.70)	73014 (17.36)	90521 (16.21)
4	83710 (9.40)	85220 (14.31)	66764 (15.87)	92849 (16.63)
5	52189 (5.86)	58195 (9.77)	51627 (12.27)	80474 (14.41)
6	33351 (3.74)	36424 (6.12)	35027 (8.33)	60915 (10.91)
7	19175 (2.15)	20313 (3.41)	19964 (4.74)	37593 (6.73)
8	9704 (1.09)	9793 (1.65)	9743 (2.31)	18796 (3.37)
9	4698 (0.53)	4115 (0.69)	4241 (1.01)	8404 (1.50)

[a] 0: 0-17,000 (cell/ml), 1: 18,000-34,000, 2: 35,000-70,000, 3: 71,000-140,000, 4: 141,000-282,000, 5: 283,000-565,000, 6: 566,000-1,130,000, 7: 1,131,000-2,262,000, 8: 2,263,000-4,525,000, 9: 4,526,000-and above.

TD milk yield = animal number + herd + year-season of calving + month of TD + calving age + weeks in lactation + previous dry period length + SCS.

Fixed effects were: herd, year-season of calving, month of TD, weeks in lactation, previous dry period length and SCS, and covariate was calving age. Animal number was considered as subject and the type of structure was defined for an autoregressive model. The subject defines the variable on which repeated measurements were taken and autoregressive model assumes that with greater distance between periods, correlations are smaller. Also, REG procedure was used to quantify amount of milk loss per each increase in SCS within each stage.

Results

Average of daily milk yield and days in milk in first, second, third and ≥fourth lactation cows were 32.93 kg, 36.08 kg, 36.72 kg and 35.20 kg, and 148.52 days, 148.04 days, 147.70 days and 146.16 days, respectively. Also, mean of SCS in first, second, third and ≥fourth lactation cows were 2.325, 2.965, 3.366 and 3.798. Table 1 shows the number of records in different SCS's classes in different lactations.

Milk yield losses associated with SCS's in different stages of lactation in lactation 1 to ≥4 are shown in Tables 2 to 5. There was a reduction in daily milk yield with increase of SCS in all lactations, and parity and stage of lactation affected the amount of reduction. For primiparous cows the range of daily milk yield deviation was from +0.619 kg for an SCS of 0 to -2.720 kg for an SCS of 9 in comparison with SCS of 3 in week 1. At the end of the lactation (week 33-44), however, the range of daily milk yield deviation for primiparous cows was from +1.730 kg for an SCS of 0 to -5.333 kg for an SCS of 9 in comparison with SCS of 2. For ≥4 lactation cows the range of daily milk yield deviation was from -0.447 kg for an SCS of 0 to -7.337 kg for an SCS of 9 in comparison with SCS of 3 in week 1. At the end of the lactation (week 33-44), however, the range of daily milk yield deviation for these cows was from +0.502 kg for an SCS of 0 to -7.905 kg for an SCS of 9 in comparison with SCS of 2. Also, regression coefficients of milk yield on SCS in different stages of lactation, based on test-day records, in first, second, third and ≥ fourth lactations are shown in Table 6. The increase in SCS leads to decrease in milk yield that was higher in later parts of lactation relative to early lactation. The regression coefficients of

Table 2. Milk yield losses associated with different SCS's in different stages of lactation in first lactation cows (expressed as deviation in comparison with milk yield at SCS of 3 in first week of lactation and SCS of 2 in rest of lactation; 890,708 test-day records for 120,149 animals from 759 herds with 43 levels for YS of calving)

SCS[a]	Week in lactation						
	1	2	3-8	9-16	17-24	25-32	33-44
0	0.619[ns]	0.583[b]	0.805[a]	0.730[a]	0.901[a]	1.177[a]	1.730[a]
1	0.796[b]	0.539[a]	0.449[a]	0.386[a]	0.456[a]	0.584[a]	0.897[a]
2	0.813[a]	--	--	--	--	--	--
3	--	-0.360[b]	-0.401[a]	-0.288[a]	-0.250[a]	-0.305[a]	-0.486[a]
4	-0.425[ns]	-0.948[a]	-0.618[a]	-0.539[a]	-0.432[a]	-0.652[a]	-0.761[a]
5	-0.946[b]	-1.210[a]	-1.028[a]	-0.760[a]	-0.757[a]	-0.884[a]	-0.981[a]
6	-0.475[ns]	-1.904[a]	-1.286[a]	-1.097[a]	-1.064[a]	-1.276[a]	-1.380[a]
7	-1.163[c]	-2.453[a]	-2.151[a]	-1.776[a]	-1.852[a]	-2.016[a]	-2.198[a]
8	-3.527[a]	-3.370[a]	-2.922[a]	-3.453[a]	-3.115[a]	-3.223[a]	-3.008[a]
9	-2.720[b]	-5.319[a]	-4.918[a]	-5.654[a]	-5.569[a]	-5.131[a]	-5.333[a]

[a] 0: 0-17,000 (cell/ml), 1: 18,000-34,000, 2: 35,000-70,000, 3: 71,000-140,000, 4: 141,000-282,000, 5: 283,000-565,000, 6: 566,000-1,130,000, 7: 1,131,000-2,262,000, 8: 2,263,000-4,525,000, 9: 4,526,000-and above. [a,b,c,d]: $p < 0.001$, $p < 0.01$, $p < 0.05$, $p < 0.1$, respectively; [ns]: non-significant.

Table 2. Milk yield losses associated with different SCS's in different stages of lactation in second lactation cows (expressed as deviation in comparison with milk yield at SCS of 3 in first week of lactation and SCS of 2 in rest of lactation; 595,469 test-day records for 79,755 animals from 638 herds with 43 levels for YS of calving)

SCS[a]	Week in lactation						
	1	2	3-8	9-16	17-24	25-32	33-44
0	0.289[ns]	0.991[a]	1.409[a]	1.308[a]	1.539[a]	1.675[a]	1.521[a]
1	0.988[c]	0.620[a]	0.585[a]	0.626[a]	0.954[a]	0.923[a]	1.075[a]
2	0.962[b]	--	--	--	--	--	--
3	--	-0.864[a]	-0.132[ns]	-0.260[a]	-0.661[a]	-0.991[a]	-1.379[a]
4	-1.783[a]	-0.756[a]	-0.478[a]	-0.431[a]	-0.920[a]	-1.730[a]	-2.564[a]
5	-1.553[a]	-1.406[a]	-0.660[a]	-0.898[a]	-1.413[a]	-2.085[a]	-3.429[a]
6	-2.163[a]	-1.942[a]	-1.394[a]	-1.401[a]	-2.110[a]	-2.715[a]	-4.083[a]
7	-4.440[a]	-2.304[a]	-2.518[a]	-2.620[a]	-2.991[a]	-3.471[a]	-4.399[a]
8	-4.710[a]	-4.493[a]	-3.951[a]	-4.206[a]	-4.266[a]	-4.845[a]	-5.181[a]
9	-5.675[b]	-4.755[a]	-6.514[a]	-7.970[a]	-7.752[a]	-7.597[a]	-7.540[a]

[a] 0: 0-17,000 (cell/ml), 1: 18,000-34,000, 2: 35,000-70,000, 3: 71,000-140,000, 4: 141,000-282,000, 5: 283,000-565,000, 6: 566,000-1,130,000, 7: 1,131,000-2,262,000, 8: 2,263,000-4,525,000, 9: 4,526,000-and above. [a,b,c,d]: $p < 0.001$, $p < 0.01$, $p < 0.05$, $p < 0.1$, respectively; [ns]: non-significant.

Table 4. Milk yield losses associated with different SCS's in different stages of lactation in third lactation cows (expressed as deviation in comparison with milk yield at SCS of 3 in first week of lactation and SCS of 2 in rest of lactation; 436,209 test-day records for 57,963 animals from 617 herds with 43 levels for YS of calving)

SCS[a]	Week in lactation						
	1	2	3-8	9-16	17-24	25-32	33-44
0	2.367[b]	1.222[a]	1.537[a]	1.434[a]	1.681[a]	1.527[a]	1.116[a]
1	0.873[ns]	0.338[ns]	0.774[a]	0.613[a]	1.014[a]	0.931[a]	0.683[a]
2	0.125[ns]	---	---	---	---	---	---
3	---	-1.256[a]	-0.203[d]	-0.524[b]	-0.801[a]	-1.127[a]	-1.556[a]
4	-0.576[ns]	-1.028[a]	-0.712[a]	-0.726[a]	-1.081[a]	-1.959[a]	-2.773[a]
5	-1.156[c]	-1.807[a]	-1.014[a]	-1.281[a]	-1.671[a]	-2.549[a]	-3.933[a]
6	-1.550[b]	-1.943[a]	-1.704[a]	-2.169[a]	-2.291[a]	-3.139[a]	-4.710[a]
7	-2.306[b]	-3.353[a]	-3.077[a]	-3.218[a]	-3.541[a]	-4.169[a]	-5.580[a]
8	-2.709[c]	-4.582[a]	-4.595[a]	-5.383[a]	-5.041[a]	-5.675[a]	-6.723[a]
9	-7.680[a]	-7.251[a]	-7.167[a]	-8.677[a]	-8.708[a]	-8.070[a]	-8.152[a]

[a] 0: 0-17,000 (cell/ml), 1: 18,000-34,000, 2: 35,000-70,000, 3: 71,000-140,000, 4: 141,000-282,000, 5: 283,000-565,000, 6: 566,000-1,130,000, 7: 1,131,000-2,262,000, 8: 2,263,000-4,525,000, 9: 4,526,000-and above. [a,b,c,d]: $p < 0.001$, $p < 0.01$, $p < 0.05$, $p < 0.1$, respectively; [ns]: non-significant.

Table 5. Milk yield losses associated with different SCS's in different stages of lactation in ≥fourth lactation cows (expressed as deviation in comparison with milk yield at SCS of 3 in first week of lactation and SCS of 2 in rest of lactation; 578,021 test-day records for 53,321 animals from 610 herds with 43 levels for YS of calving)

SCS[a]	Week in lactation						
	1	2	3-8	9-16	17-24	25-32	33-44
0	-0.447[ns]	0.671[d]	1.389[a]	1.343[a]	1.638[a]	1.389[a]	0.502[b]
1	-0.394[ns]	0.518[c]	0.781[a]	0.524[a]	0.938[a]	1.047[a]	0.676[a]
2	0.071[ns]	---	---	---	---	---	---
3	---	-0.961[a]	-0.242[c]	-0.240[b]	-0.595[a]	-0.963[a]	-1.086[a]
4	-0.932[c]	-0.904[a]	-0.648[a]	-0.670[a]	-1.041[a]	-1.751[a]	-2.299[a]
5	-1.793[a]	-0.970[a]	-1.071[a]	-1.460[a]	-1.770[a]	-2.347[a]	-3.395[a]
6	-1.616[b]	-1.660[a]	-1.913[a]	-2.029[a]	-2.361[a]	-3.193[a]	-4.287[a]
7	-2.625[a]	-3.089[a]	-3.343[a]	-3.565[a]	-3.830[a]	-4.305[a]	-5.023[a]
8	-4.293[a]	-4.119[a]	-5.235[a]	-5.439[a]	-5.724[a]	-5.733[a]	-5.913[a]
9	-7.337[a]	-6.555[a]	-8.325[a]	-8.892[a]	-8.632[a]	-8.562[a]	-7.905[a]

[a] 0: 0-17,000 (cell/ml), 1: 18,000-34,000, 2: 35,000-70,000, 3: 71,000-140,000, 4: 141,000-282,000, 5: 283,000-565,000, 6: 566,000-1,130,000, 7: 1,131,000-2,262,000, 8: 2,263,000-4,525,000, 9: 4,526,000-and above. [a,b,c,d]: $p < 0.001$, $p < 0.01$, $p < 0.05$, $p < 0.1$, respectively; [ns]: non-significant.

Table 6. Linear regression coefficients of milk yield on SCS in different stages of lactation in different lactation cows, based on test-day records

Parity	Week in lactation					
	1-2	3-8	9-16	17-24	25-32	33-44
1st parity cows	-0.565	-0.539	-0.581	-0.577	-0.586	-0.635
2nd parity cows	-0.626	-0.725	-0.814	-0.848	-0.889	-0.947
3rd parity cows	-0.777	-0.825	-0.937	-0.962	-0.970	-1.053
≥4th parity cows	-0.694	-0.919	-0.957	-0.995	-1.005	-0.955

All values were significant at $p < 0.001$.

milk yield on SCS ranged from -0.565 to -0.635 for primiparous cows and from -0.626 to -1.053 for multiparous cows.

Discussion

Multiparous cows had higher SCS. It has been shown that parity has a significant effect on SCC (Olde Riekerink et al., 2007; Chegini, 2010) and multiparous cows have higher SCC.

Milk yield deviation associated with SCS's was from +0.619 kg to -5.333 kg for primiparous cows and from -0.447 kg to -7.905 kg for multiparous cows. The corresponding figures estimated by Jones et al. (1983) were from 0.73 kg to -3.64 kg for first lactation cows and from 1.77 kg to -5.61 kg for later lactations. Haile-Mariam et al. (2001) conducted a study to estimate genetic and environmental correlations between test-day yield traits and SCC using a random sire model. They reported higher absolute values for genetic and environmental correlation between milk yield and SCC in later stages of lactation relative to earlier stages of lactation. Hortet et al. (1999) suggested that udder infection can cause permanent grandular damage and this is responsible for higher milk reduction in late lactation. By discarding data of lactations preceding by a lactation affected by mastitis, Hagnestam-Nielsen et al. (2009) performed an experiment that could test the accuracy of this hypothesis. Their results showed that a clinical mastitis in previous lactation could not affect milk yield in later lactations. It seems that high SCC can accelerate the degeneration of milk secretory cells and the catabolic process. Table 6 shows linear regression coefficients of milk yield on SCS in different stages of lactation in different lactation cows. Multiparous cows had a higher milk loss with increased SCS. This result is in accordance with the results of previous studies (Kennedy et al., 1982; Jones et al., 1983; Hortet et al., 1999; Norman et al., 1999; de los Campos et al., 2006; Hagnestam et al., 2007; Dürr et al., 2008; Rekik et al., 2008; Hagnestam-Nielsen et al., 2009). The reports of phenotypic correlation between milk yield and SCC ranged from -0.05 for first parity cows to -0.18 for later parity cows (Kennedy et al., 1982; Norman et al., 1999). In case of dilution effect, using structural equations and considering the recursive effect of SCS on milk yield, de los Campos et al. (2006) mentioned that the negative effect of disease on milk yield created the negative phenotypic correlation between SCS and milk yield and that a dilution effect would not be an important cause of this phenotypic correlation.

It had been demonstrated that first lactation cows have higher persistency (Weller et al., 1987; Gengler, 1996; Chegini, 2010). This is because of higher ability of their udder tissues to recover and regenerate secreting cells and better consequence of mammary cell death and regeneration in advantage of regeneration. Therefore, it can be concluded that with increasing number of lactation the effect of SCC would be intensified on the rate of secretory cells degeneration and multiparous cows with lower rates suffer more. Investigating on the relationship between milk yield and SCC, Chegini (2010) found a negative genetic correlation between milk persistency and different measures of SCC (ranged from -0.11 to -0.42). Also, Haile-Mariam et al. (2003) reported a negative genetic correlation (-0.29) between mean of natural logarithm of SCC with milk persistency.

Contrary to the results of Hagnestam-Nielsen et al. (2009), the weakest association between SCS and daily milk yield was found in lactation week 1 to 2 in all lactations. Since mean of SCC in early lactation is high (most of cows have high SCC in this period), it can be concluded that increase of SCC early in lactation is an intrinsic phenomenon and plays a protective role relative to increase of SCC in later parts of lactation. The effect of SCC on milk yield is different from the effect of mastitis on milk yield. Estimating the regression coefficient of milk yield on SCS, Hagnestam-Nielsen et al. (2009) reported that multiparous cows with mastitis event in previous lactation experienced less severe milk loss in present lactation. However, since there was no record for mastitis, we could not include the effect of this disease in the model.

Conclusion

Cows in third lactation had the highest daily milk yield and cows in first lactation had the lowest SCS. In all lactations, there was a reduction in daily milk yield with increase of SCS, and parity and stage of lactation affected the amount of reduction. Reduction in milk yield associated with increase of SCS was higher with increase of parity and stage of lactation. This research is one of the few studies to examine the effect of SCS on daily milk yield, using a large dataset.

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