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Associations between somatic cell score of milk and fertility traits in Polish Holstein-Friesian cows*

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The study aimed at estimating the association between somatic cell score (SCS) and two fertility traits: non-returns to oestrus by 56 days (NR56), and number of days from calving to first insemination (CFI). The data were records of 298,016 test-day observations from 190,279 first and second lactation of Polish Holstein-Friesian (PHF) cows. The model used to evaluate the effect of preceding test-day SCS on NR56 included random herd effect and fixed effects of parity, year of calving, lactation stage at first insemination, month of first insemination, interval between preceding test-day and day of first insemination, and linear regression of NR56 on SCS. A similar model including fixed effects of parity, year of calving, month of first insemination, linear and quadratic regressions of CFI on SCS, and random herd effect was applied to analyse the relation between test-day SCS and CFI. All fixed effects except the number of days from preceding test-day to first insemination significantly affected NR56. Fixed effects included in the linear model for CFI analysis, *i.e.* parity, year of calving, and month of first insemination, were also significant. Negative regression coefficients of NR56 on preceding test-day SCS, by interval between day of preceding test and first insemination, showed that within each interval an increase in test-day SCS caused a decrease in the non-return rate. The significant linear and quadratic regressions of CFI on SCS indicate that high SCS might delay the first insemination.

KEY WORDS: dairy cows / fertility / insemination / lactation / non-return rate / somatic cell score

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Mastitis and infertility cause considerable economic losses in dairy production. Somatic cell count is a universally used measure of udder infections. The average estimate of genetic correlations between *mastitis* and somatic cell count reported in the literature was 0.6, ranging between 0.1 and 0.78 [Emanuelson *et al*. 1988, Heringstad *et al*. 2000].

Fertility is characterized by several traits usually of low heritabilities [Andersen-Ranberg *et al*. 2005, Jagusiak 2005ab]. Non-return rate and interval from calving to first insemination are considered good indicators of reproduction performance and are included in fertility indexes. [Gonzalez-Recio and Alenda 2005].

The influence of *mastitis* on the reproductive performance of dairy cows has been studied by several authors. Barker *et al*. [1998] reported a negative effect of clinical *mastitis* during early lactation on fertility traits: onset of clinical *mastitis* before first service increased the number of days to first service and days open, and also the number of services per conception. Miller *et al*. [2001] found no significant relationship between elevated SCS before first insemination and non-return rate in Jerseys, but a small linear regression of non-return rate on preceding test-day SCS in Holsteins, recorded within 2 to 3 weeks before insemination. They also showed a significant quadratic regression of number of days from calving to first insemination on SCS. In Israeli Holsteins, Weller and Ezra [1997] reported a genetic correlation of -0.366 between conception index and lactational SCS mean.

The purpose of this study was to analyse the relations between test-day SCS prior to the first insemination, rate of non-return to day 56, and number of days from calving to first insemination in Polish Holstein-Friesian cows. Moreover, assessed was the influence of fixed effects on fertility traits.

Material and methods

The data from the SYMLEK milk recording system consisted of 298,016 test-day observations from 190,279 first and second lactations of Polish Holstein-Friesian (PHF) cows that calved from 1999 through 2005 in 4999 herds. The records contained cow identification, herd, parity, test-day somatic cell count (SCC), and insemination and calving dates. A requirement of a minimum 20 cows per herd was imposed. SCC was log-transformed to somatic cell score (SCS) as follows:

$$SCS = \log_2(SCC/100{,}000) + 3$$

Fertility was measured by non-return rate to day 56 (NR56) and number of days from calving to first insemination (CFI). Non-return rate to day 56 was defined as the proportion of cows not subjected to a second insemination within 56 days of first insemination.

Twelve stages of lactation were defined: <50 days, 10-day intervals from 51 to 150, and one interval from 151 to 365 days. The interval between day of preceding test-day and day of first insemination was divided into weekly intervals from 1 to 35 days and one interval from 36 to 63 days.

The effect of preceding test-day SCS on NR56 was evaluated according to the following model:

$$y_{ijklmno} = h_i + p_j + c_k + m_l + st_m + t_n + b_n \times SCS_{ijklmno} + e_{ijklmno}$$

where:

$y_{ijklmno}$ – NR56 of cow o in the *n*-th class of the interval between preceding test-day and day of first insemination, *i*-th herd, *j*-th parity, *k*-th year of calving, *l*-th month of first insemination, and *m*-th lactation stage at first insemination;

h_i – random effect of *i*-th herd;

p_j – fixed effect of *j*-th parity;

c_k – fixed effect of *k*-th year of calving;

m_l – fixed effect of month of first insemination *l*;

st_m – fixed effect of lactation stage at first insemination *m*;

t_n – fixed effect of *n*-th class of interval between preceding test day and day of first insemination;

b_n – coefficient of linear regression of NR56 on SCS in the *n*-th class of interval between preceding test-day and day of first insemination;

$e_{ijklmno}$ – random residual effect.

The effect of preceding test-day SCS on CFI was evaluated according to the following model:

$$y_{ijklm} = h_i + p_j + c_k + m_l + b_1 \times SCS_{ijklm} + b_2 \times SCS^2_{ijklm} + e_{ijklm}$$

where:

y_{ijklm} – CFI of cow m in herd *i*, parity *j*, year of calving *k*, month of first insemination *l*;

h_i – random effect of *i*-th herd;

p_j – fixed effect of *j*-th parity;

c_k – fixed effect of *k*-th year of calving;

m_l – fixed effect *l*-th month of first insemination;

b_1 – coefficient of linear regression of CFI on SCS;

b_2 – coefficient of quadratic regression of CFI on SCS;

e_{ijklmn} – random residual effect.

PROC MIXED REML [SAS 2001] was used to fit both described models.

Results and discussion

Descriptive statistics of the studied traits are given in Table 1. Average SCS were similar to the results of other studies on Polish Holstein-Friesians. In the first lactation, mean SCS (3.13) was lower than in the second (3.34). Ptak *et al*. [2007] found lower average SCS in the first than in the second lactation (3.07 and 3.78, respectively). In studies on the relationship between milk yield and SCS, Miller *et al*. [2004] observed slightly lower SCS averages in the first (2.85) than in the second parity (3.11). Neuenschwander *et al* [2005] in Swiss Holsteins reported the average SCS to be 2.48, but the mean SCS increased with consecutive parities from 2.13 to 2.81. Mean NR56 (Tab. 1) was slightly lower in the first (60.39%) than in the second parity (61.33%), with the grand mean value of 60.73%. As demonstrated in Canadian Holsteins the non-return rate was higher in the first (0.74) than in later parities (0.57) – Jamrozik *et al*. [2005]. Non-return rate to day 56 as reported by Andersen-Ranberg *et al*. [2005] in Norwegian Red cattle was 67% in the first parity, being much higher than in our report presented here.

Table 1. Means and standard deviations (SD) for somatic cell score (SCS) and calving to first insemination interval (CFI) and non-returns to oestrus (%) by day 56 (NR56) by parity

Parity	n	SCS		CFI (days)		NR56
		mean	SD	mean	SD	(%)
1	190,279	3.13	1.35	88.9	40.2	60.39
2	107,737	3.34	1.46	86.6	38.5	61.33
AU	298,016	3.21	1.39	88.1	39.6	60.73

Mean CFI period was longer in the first parity (88.9 days) than in the second parity (86.6 days); with the overall mean of 88.1 days (Tab.1). The mean CFIs calculated from our data were similar to the averages reported for the North American Holstein-Friesian population by Van Doormaal *et al.* [2004] and Jamrozik *et a*l. [2005], and slightly higher than those obtained by Miller *et al.* [2001]. An earlier study of the population of Polish Holstein-Friesians showed much shorter CFI (79.3 days) in the first parity [Jagusiak 2005b], closer to results reported for Swiss Holstein-Friesians by Neuenschwander *et al*. [2005].

All fixed effects except for interval between preceding test-day and day of first insemination (*i.e*. effects of parity, year of calving, lactation stage at first insemination, month of first insemination) had a highly significant effect on NR56.

Least squares means of NR56 increased from first to second parity by 1% (Tab. 2). Miller *et al*. [2001] reported a decline in non-return rate from 56% in first to about 50% in the sixth parity. In Canadian Holsteins, Jamrozik *et al*. [2005] found a much deeper decline in NR56, from 0.74 in the first to 0.57 in later parities.

NR56 showed small fluctuations between 1999 and 2004, but a 4% increase in 2005 (Tab. 2). The lowest NR56 was in August (61.4%) and the highest (68.6%) in

November, with no regular seasonality. Miller *et al*. [2001] found a large decline of the non- return rate in summer months.

Table 2. Least squares means (LSM) and standard errors (SE) for non returns by day 56 (NR56) and calving to first insemination interval (CFI) by parity, year of calving, month of first insemination, stage of lactation at first insemination and interval between preceding test-day and day of first insemination

Effect		n	NR56 (%)		CFI	
			LSM	SE	LSM	SE
Parity	1	190279	64.4	0.19	91.2	0.23
	2	107737	65.4	0.22	88.1	0.24
Year of calving	1999	21796	63.7	0.37	86.4	0.34
	2000	44204	63.6	0.28	85.7	0.28
	2001	49483	64.4	0.27	88.8	0.27
	2002	51657	64.9	0.26	90.9	0.27
	2003	48217	64.3	0.27	92.8	0.27
	2004	52848	64.6	0.26	94.4	0.27
	2005	29811	68.6	0.33	88.4	0.31
Month of first insemination	1	19688	64.3	0.38	89.5	0.34
	2	23330	63.5	0.36	88.7	0.33
	3	28259	64.8	0.33	87.6	0.31
	4	26611	65.8	0.34	87.5	0.31
	5	27897	64.9	0.33	88.6	0.31
	6	27474	65.1	0.33	90.1	0.31
	7	28049	63.4	0.33	90.8	0.31
	8	25576	61.4	0.34	91.7	0.32
	9	25233	63.3	0.34	91.4	0.32
	10	25147	66.4	0.34	89.2	0.32
	11	21842	68.6	0.36	90.6	0.33
	12	18910	67.1	0.39	89.8	0.35
Stage of lactation (days)	≤50	33600	56.9	0.31	-	-
	51-60	36585	60.5	0.29	-	-
	61-70	43798	62.4	0.28	-	-
	71-80	40407	63.8	0.28	-	-
	81-90	33806	65.0	0.30	-	-
	91-100	26891	65.5	0.33	-	-
	101-110	20427	65.7	0.37	-	-
	111-120	15185	66.1	0.42	-	-
	121-130	11445	66.6	0.47	-	-
	131-140	8505	66.8	0.54	-	-
	141-150	6319	68.6	0.62	-	-
	151-365	21048	70.7	0.37	-	-
Interval (days)	1-7	59586	65.1	0.25	-	-
	8-14	59549	64.8	0.25	-	-
	15-21	59410	64.7	0.25	-	-
	22-28	57221	64.7	0.26	-	-
	29-35	28453	65.2	0.33	-	-
	36-63	33797	64.9	0.31	-	-

LSM of NR56 showed a clear pattern which was related to lactation stage: lowest (56.9%) in the first stage of lactation (< 50 days in milk) and rising to 70.7% in second half of lactation.

Length of interval between day of preceding test and day of first insemination did not display any obvious relationship with NR56.

Fixed effects of parity, year of calving, and month of first service significantly influenced CFI. This finding is in accordance with the results reported by Miller *et al*. [2001] showing all studied fixed effects to be significant.

Least squares mean of CFI in the first parity was found by 3.1 days longer than in the second (Tab. 2). Between 2000 through 2004 CFI increased by 8.7 days; the two extreme years – 1999 and 2005, not considered – were represented by a small number of observations. The shortest CFI periods were observed in March (87.6 days) and April (87.5 days), while the longest in August (91.7 days) and September (91.4 days). CFIs obtained by Miller *et al*. [2001] were shorter than in the present report: maximum 89 days in June-July and minimum 82 days in autumn and winter.

Regression coefficients of NR56 on preceding test-day SCS, by interval between day of preceding test and first insemination, were highly significant ($P<0.0001$) and negative (Tab. 3). The coefficients ranged from -0.497 to -0.762 and did not display a regular pattern. The negative coefficients indicated that within each interval an increase in test-day SCS caused a decrease in non-return rate. An increase by one SCS unit caused a 0.5-0.8% decrease in NR56. A similar relationship between SCS and NR70 was reported by Miller *et al* [2001] who in most cases found the regression coefficients to be negative, but slightly smaller.

Table 3. Coefficients of regression and standard errors (SE) of rate of oestrus non-returns to day 56 (NR56) on preceding test-day somatic cell score (SCS) by the interval between day of preceding test and day of first insemination

Interval (days)	Coefficient of regression*	SE
1–7	-0.617	0.1432
8-14	-0.762	0.1427
15-21	-0.497	0.1430
22-28	-0.560	0.1441
29-35	-0.738	0.2039
36-63	-0.562	0.1863

*All coefficients significant at $P<0.03$.

The significant linear and quadratic regressions showed that at the beginning the CFI increased with SCS, but later, with higher values of SCS, the interval from calving to first insemination slightly declined (Tab. 4). This indicates that high SCS might delay the first insemination. In the study by Miller *et al*. [2001], the signs of the linear and quadratic regression coefficients were the opposite of ours presented

Table 4. Coefficients of regression and standard errors (SE) of days from calving to first insemination (CFI) on preceding test-day somatic cell score

Regression	Coefficient of regression*	SE
Linear	5.2332	0.20660
Quadratic	-0.3733	0.02697

*All coefficients significant at P<0.001.

here, but also indicated that the first insemination after calving was delayed in cows with high SCS. Pryce *et al*. [1998] reported a near-zero (0.05) phenotypic correlation between the CFI and average lactational SCS, and the genetic correlation of 0.16.

Poor health and low fertility negatively alter the economics of dairy breeding by reducing production and increasing involuntary culling. Our results showed that elevated SCS as an indicator of *mastitis* within each interval of preceding test-day to first insemination caused a decrease in the non-return rate. The significant linear and quadratic regressions of CFI on SCS suggest that high SCS might delay the first insemination.

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Współzależność między zawartością komórek somatycznych w mleku a cechami płodności krów rasy polskiej holsztyńsko-fryzyjskiej

S t r e s z c z e n i e

Badano wpływ zawartości komórek somatycznych (transformowanych logarytmicznie na SCS) w mleku na wskaźnik niepowtarzalności unasienienia do 56 dnia po pierwszym zabiegu inseminacyjnym (*non-return to oestrus by day 56* – NR56) oraz na liczbę dni od ocielenia do pierwszego unasienienia (*calving to first insemination* – CFI). Dane obejmowały 298 016 próbnych udojów pochodzących z pierwszych i drugich laktacji 190 279 krów rasy polskiej holsztyńsko-fryzyjskiej, ocielonych w latach 1999-2005. Wpływ poziomu komórek somatycznych (SCS) w próbnym udoju poprzedzającym pierwsze unasienienie na NR56 zbadano stosując model liniowy, który uwzględniał: losowy efekt stada oraz stałe efekty laktacji, roku ocielenia, miesiąca pierwszej inseminacji, podklasy liczby dni od ostatniego próbnego udoju do dnia pierwszej inseminacji i regresję liniową na SCS. Podobny model, zawierający stałe efekty laktacji, roku cielenia, miesiąca pierwszej inseminacji, liniową i kwadratową regresję na SCS oraz losowy efekt stada zastosowano do analizy zależności między SCS a CFI. Wszystkie efekty stałe, z wyjątkiem liczby dni między próbnym udojem a zabiegiem pierwszej inseminacji w modelu dla NR56, wpływały istotnie na badane cechy płodności. Ujemne współczynniki regresji liniowej NR56 na SCS, stwierdzone w obrębie każdej podklasy liczby dni od ocielenia do pierwszej inseminacji wskazują, że podwyższony poziom komórek somatycznych w próbnym udoju pochodzącym sprzed pierwszego unasienienia, obniża skuteczność unasieniania. Uzyskane współczynniki regresji liniowej i kwadratowej CFI na SCS wskazują, że podwyższona liczba komórek somatycznych może opóźnić pierwszą inseminację.