# Relationship of Somatic Cell Score and Linear Type Trait Evaluations of Holstein Sires

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## ABSTRACT

Genetic evaluations of Holstein bulls for mean somatic cell score were compared with their standardized transmitting abilities for linear type traits. Based on first lactation daughter information from five dairy records processing centers, PTA for somatic cell scores for 712 sires ranged from −.50 to .56. Standardized transmitting abilities for 14 type traits were provided for these bulls by the Holstein Association. Mean transmitting abilities for udder traits were negative for the 100 bulls with highest PTA and positive for the 100 bulls with lowest PTA for somatic cell score. For all bulls, correlations of PTA for somatic cell score with udder trait evaluations were negative (−.31 for fore udder attachment, −.28 for udder depth, −.21 for front teat placement, −.17 for rear udder width, −.16 for udder cleft, and −.13 for rear udder height). The best five-trait model to predict PTA for somatic cell score consisted of transmitting abilities for fore udder attachment, thurl width, strength, dairy form, and body depth ($R^2$ = .142). If PTA for milk yield was included with evaluations for type traits, it replaced dairy form in the model. Inclusion of quadratic terms did not contribute greatly to prediction of PTA for somatic cell score. Selection for higher, more firmly attached udders should contribute to reducing somatic cell scores.
(**Key words**: linear type, somatic cell score, genetic evaluation, Holstein)

**Abbreviation key: SCS** = linear somatic cell score, **STA** = standardized transmitting ability.

## INTRODUCTION

Genetic correlations between SCC and mastitis are moderately high (2), and the possibility of calculating genetic evaluations of SCC for dairy cattle with modern techniques has been clearly demonstrated (1). Several Scandinavian countries currently have selection programs in place, and evaluations are being developed for the US and Canada. Appropriate selection intensity to place on SCC is yet to be determined. Strandberg and Shook (11) demonstrated that selection to reduce the rate of increase in mastitis that accompanies selection for milk yield could be economically prudent. Rogers (5) suggested an index that combines linear type traits with production and SCC.

In 1960, Young et al. (15) compared genetic relationships between conformation traits and measures of mastitis. They reported genetic correlations with udder depth of −.28 for clinical mastitis, −.38 for bacterial infections, and −.48 for milk leukocyte counts. Thomas et al. (12) compared multiple regressions of lactation average of natural logarithm of SCC on linear scores and objective measures of conformation traits. They determined that selection to reduce frequencies of cows with deep udders, especially low rear udders, widely placed teats, rear teats too far back, and short and wide teats may modestly augment efforts to reduce inci-

Received July 31, 1992.
Accepted October 2, 1992.
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dence of mastitis through improved management.

Seykora and McDaniel (9) examined relationships among several udder traits, SCC, and milk yield. Genetic correlations with lactation SCC were −.41 for fore udder height, −.44 for rear udder height, .20 for cleft depth, and .21 for udder levelness. In a Canadian study, Monardes et al. (4) reported smaller genetic correlations of SCC with a number of conformation traits. Genetic correlations with SCC were .02 for final class, .01 for mammary system, −.04 for fore udder, −.14 for rear udder, −.10 for udder texture, −.16 for fore attachment, .15 for rear attachment, −.15 for median suspensory ligament, .03 for fore teat placement, and .01 for rear teat placement.

Rogers et al. (6) compared linear somatic cell score (**SCS**) data from Pennsylvania DHIA programs with conformation data provided separately by Sire Power, Inc. (Tunkhannock, PA) and the Holstein Association (Brattleboro, VT). Genetic correlations with SCS were of greatest magnitude for udder traits. Genetic correlations of first lactation SCS with udder depth ranged from −.21 to −.42, depending on the data used. These correlations indicated that daughters of sires with deeper udders had elevated SCS. First lactation SCS also was negatively related to fore udder attachment (−.41 to −.47) and front teat placement (−.18 to −.51). Rogers et al. (6) concluded that selection for higher udders and closer teat placement would likely improve resistance to mastitis in dairy cattle.

The objectives of this study were to examine the relationships between genetic evaluations of SCS and linear type traits of Holstein sires and to determine the ability of standardized evaluations for linear type traits to predict a sire's PTA for SCS.

## MATERIALS AND METHODS

Genetic evaluations for SCS were those of Boettcher et al. (1) for 778 Holstein bulls. The SCS trait for these evaluations was simple lactation average of sample day linear scores ($\log_2$ scale) adjusted for calving age, calving season, and DIM at last SCS sample day. Evaluations included only first lactation Holstein records from five dairy records processing centers (Agri-Tech Analytics, Tulare, CA; Cornell Dairy Records Processing Laboratory, Ithaca, NY; Pennsylvania DHIA Service Center, University Park; Dairy Records Processing Center at Raleigh, NC; and Wisconsin DHI Cooperative, Madison); records from Vermont, Indiana, and West Virginia were excluded because those states are geographically remote from their processing centers. Calvings from January 1987 through October 1989 were included. Lactation records were required to have at least 15 DIM, protein information, and no more than 20 sample d.

The PTA for SCS of Holstein sires were from a multiple-trait REML procedure that gave an estimate of .10 for heritabilty and BLUP of transmitting abilities for sires (1). Standardized (305-d lactation, twice daily milking, mature equivalent) yields of milk, fat, and protein also were included in the evaluation. The model included the effect of herd-year-season. Sires included had at least 25 daughters, and relationships among common ancestors (sires and maternal grandsires) were included. The final analysis had 241,786 daughters of 778 sires (plus 66 related sires with no daughters) from 32,094 herd-year-seasons.

Genetic evaluations for milk yield were July 1991 USDA-DHIA PTA calculated from a single-trait animal model that considered the first five lactations of daughters, provided that a first lactation record was present (14). July 1991 genetic evaluations for linear type traits were provided by the Holstein Association for 712 of the sires. Linear type evaluations were computed using a multiple-trait BLUP sire model (13). Only the daughter score closest to 30 mo of age was considered for each of the 14 traits routinely recorded by Holstein Association evaluators. All traits were analyzed simultaneously, which allowed incorporation of genetic relationships between traits. Linear PTA were expressed on a standardized scale and reported as standardized transmitting abilities (**STA**). Holstein bulls with semen currently available were used as a base population with a mean of 0 and a standard deviation of 1 for STA of each linear type trait.

Evaluations of SCS, linear type traits, and milk yield were combined for the 712 sires with complete information. Means of type traits were compared for the 100 bulls with highest (least favorable) or lowest (most favorable) PTA for SCS. Correlations between PTA for SCS and STA for linear type traits were computed. Stepwise regression techniques [the STEPWISE option of the SAS®

TABLE 1. The PTA for somatic cell score (SCS) and milk yield and the standardized transmitting abilities (STA) for linear type traits of 712 Holstein bulls.

| Trait | $\overline{X}$ | SD |
|---|---|---|
| PTA | | |
| SCS | −.01 | .16 |
| Milk, kg | 318 | 313 |
| STA | | |
| Udder cleft | −.33 | 1.21 |
| Rear udder height | −.38 | 1.17 |
| Rear udder width | −.44 | 1.15 |
| Udder depth | −.47 | 1.23 |
| Fore udder attachment | −.48 | 1.25 |
| Front teat placement | −.24 | 1.32 |
| Leg set | .19 | 1.28 |
| Foot angle | −.27 | 1.40 |
| Rump angle | .26 | 1.23 |
| Thurl width | −.16 | 1.18 |
| Dairy form | −.32 | 1.11 |
| Body depth | −.19 | 1.17 |
| Strength | −.17 | 1.13 |
| Stature | −.29 | 1.14 |

regression procedure (7)] were used to determine the ability of STA for type to predict PTA for SCS. Any variable entering the model at each step was required to be significant at the .15 level, as were all variables remaining in the model. Contribution of quadratic terms for STA of type traits also was considered.

## RESULTS AND DISCUSSION

Overall means and standard deviations of PTA for SCS and milk and STA for 14 linear type traits are in Table 1. Mean PTA for SCS of the 712 sires was near 0, and standard deviation was .16, which was almost identical to values reported by Boettcher et al. (1) for the 844 bulls (sires and maternal grandsires) in the original study. Means of STA for linear type traits were negative except for leg set and rump angle, which are traits for which the intermediate may be optimal. Although STA were standardized PTA, the group of bulls studied differed from the base population (bulls with large numbers of daughter records vs. bulls with semen currently available). Perhaps for these older, more popular AI sires often chosen for their high PTA for production traits, STA for udder scores tended to be more negative. Misztal et al. (3) reported negative genetic correlations of milk yield with fore udder attachment, udder depth, and front teat placement and concluded that selection for only increased milk yield would cause deterioration of some udder traits. The 712 sires had an average of 264 effective daughters for PTA for SCS, and average reliability was 94% for PTA for milk yield (4477 daughters per sire) and 88% for STA of linear type traits (1519 daughters per sire).

Mean PTA for SCS and milk yield and mean STA for linear type traits are in Table 2 for the 100 bulls with highest PTA for SCS (.17 to .56) and the 100 bulls with lowest PTA for SCS (−.18 to −.50). The highest 100 bulls had a mean PTA for milk yield that was 134 kg more than that for the lowest 100 bulls, which was not a large difference compared with the mean (318 kg) or standard deviation (313 kg) for all 712 bulls. This result concurs with the positive genetic correlation of about .15 between SCS and milk yield for first lactation cows in recent studies (1, 8).

Mean STA for udder traits were negative for the 100 bulls with highest PTA for SCS and positive for the 100 with lowest PTA for SCS (Table 2). In other words, udder evaluations were higher for daughters of sires with low daughter SCS, a possible indication of

TABLE 2. Mean PTA for somatic cell score (SCS) and milk yield and mean standardized transmitting abilities (STA) for linear type traits for the 100 bulls with highest or lowest PTA SCS.

| | Mean PTA SCS | |
|---|---|---|
| Trait | Highest | Lowest |
| PTA | | |
| SCS | .25 | −.25** |
| Milk, kg | 380 | 246** |
| STA | | |
| Udder cleft | −.51 | .19** |
| Rear udder height | −.36 | .13** |
| Rear udder width | −.47 | .13** |
| Udder depth | −.92 | .10** |
| Fore udder attachment | −.94 | .22** |
| Front teat placement | −.69 | .23** |
| Leg set | .18 | .31 |
| Foot angle | −.18 | .01 |
| Rump angle | .21 | .16 |
| Thurl width | −.26 | .37** |
| Dairy form | −.11 | −.43* |
| Body depth | −.20 | .20** |
| Strength | −.18 | .25** |
| Stature | −.31 | .05* |

*$P > t \leq .05$.

**$P > t \leq .01$.

TABLE 3. Correlations among PTA for somatic cell score (SCS), PTA for milk yield and standardized transmitting abilities (STA) for linear type traits.

| | r[1] | |
|---|---|---|
| Trait | PTA SCS | PTA Milk |
| PTA Milk | .13 | . . . |
| STA | | |
| Udder cleft | −.16** | .03 |
| Rear udder height | −.13** | .06** |
| Rear udder width | −.17** | .12** |
| Udder depth | −.28** | −.29** |
| Fore udder attachment | −.31** | −.23** |
| Front teat placement | −.21** | −.04 |
| Leg set | .01 | −.02 |
| Foot angle | −.07 | .01 |
| Rump angle | .04 | .12** |
| Thurl width | −.18** | −.07 |
| Dairy form | .08* | .45** |
| Body depth | −.10* | −.03 |
| Strength | −.11** | −.11** |
| Stature | −.11** | −.08* |

[1]Pearson correlation coefficient.

*$P$ > |R| under the null hypothesis that R = 0 ≤ .05.

**$P$ > |R| under the null hypothesis that R = 0 ≤ .01.

TABLE 4. Stepwise regression of PTA for somatic cell score on standardized transmitting abilities for 14 linear type traits.

| Step | Type trait entered | Model $R^2$ |
|---|---|---|
| 1 | Fore udder attachment | .098 |
| 2 | Thurl width | .108 |
| 3 | Strength | .119 |
| 4 | Dairy form | .123 |
| 5 | Body depth | .142 |
| 6 | Rump angle | .147 |

decreased mastitis incidence. Largest differences between the two groups of bulls in STA for udder traits were for fore udder attachment, udder depth, and front teat placement. Mean STA for other linear type traits were significantly different ($P < .01$) between the two bull groups for thurl width, body depth, and strength.

Pearson correlations of PTA for SCS with STA for linear type traits are in Table 3. Results correspond to differences between group means in Table 2. These correlations are comparable with genetic correlations, but they may be influenced by possible environmental correlations between SCS and linear type traits because some information from some daughters was present in both SCS and type evaluations. These relationships were similar to the genetic correlations between first lactation SCC and Holstein Association type evaluations measured in different herds reported by Rogers et al. (6).

Correlations with PTA for SCS were of greatest magnitude for udder traits; STA for fore udder attachment, udder depth, and front teat placement were most negatively associated with PTA for SCS. Rogers et al. (6) found that negative genetic correlations between udder traits and first lactation SCC were of greater magnitude (−.41 for fore udder attachment, −.42 for udder depth, and −.31 for front teat placement). In their study, phenotypic correlations between SCS and udder traits were smaller in magnitude than genetic correlations, suggesting that environmental correlations were close to 0 or possibly positive. Because correlations in this study were not completely free of environmental effects, they may be biased toward 0. Also, PTA and STA are regressed toward a mean based on amount of information included. In general, even with independent data sets, correlations among PTA are expected to be smaller in magnitude than genetic correlations because PTA are regressed. These issues may explain why correlations in this study were of lesser magnitude than those reported by Rogers et al. (6). However, their conclusion that high, tightly attached udders with close front teats are desirable is supported by this study as well as results of Monardes et al. (4), Seykora and McDaniel (9), and Thomas et al. (12).

Correlation between PTA for SCS and PTA for milk yield was .13 (Table 3), and PTA for milk yield was negatively associated with STA for udder depth (−.29), fore udder attachment (−.23), and front teat placement (−.04). For these three type traits, Misztal et al. (3) found genetic correlations of −.44, −.31, and −.03, respectively, with milk yield.

Correlations of PTA for SCS with STA for thurl width (−.18), strength (−.11), and stature (−.11) were significantly negative ($P < .01$) (Table 3) and were comparable with the genetic correlations of Rogers et al. (6) of −.21, −.06, and −.11. Thomas et al. (12) also noted a negative relationship between rump width and measures of mastitis. Biological explanations for these results are unclear. Perhaps for young cows a decreased incidence of mastitis (as indicated by lower SCS) is evidence of better general health and is associated

TABLE 5. Stepwise regression of PTA for somatic cell score on standardized transmitting abilities for 13 linear type traits (fore udder attachment excluded).

| Step | Type trait entered | Model $R^2$ |
|---|---|---|
| 1 | Udder depth | .078 |
| 2 | Thurl width | .098 |
| 3 | Stature | .118 |
| 4 | Front teat placement | .122 |
| 5 | Rump angle | .126 |
| 6 | Body depth | .129 |
| 7 | Strength | .138 |
| 8 | Front teat placement[1] | .136 |
| 9 | Dairy form | .145 |

[1]Type trait removed.

with more rapid growth. In this study, STA for linear type traits were based on the daughter score nearest to 30 mo of age.

The relationship between PTA for SCS and STA for dairy form was smaller (.08 vs. .18) than that found by Rogers et al. (6). This positive relationship was probably an artifact of the positive genetic relationship between milk yield and SCS in first lactation cows (1, 8) and the high positive genetic association between milk yield and dairy form (3). The partial correlation was smaller (.03) between PTA for SCS and STA for dairy form when PTA for milk yield was held constant. A similar association with milk yield did not account for the negative correlations of PTA for SCS with STA for thurl width, strength, and stature. Correlations of STA with PTA for milk yield were –.07 for thurl width, –.11 for strength, and –.08 for stature. When PTA for milk yield was held constant, partial correlations between PTA for SCS and the STA for those three traits were nearly identical to the correlations in Table 3. However, Misztal et al. (3) reported small positive genetic correlations with milk yield for these traits. In agreement with the findings of Rogers et al. (6), PTA for SCS was not closely related genetically to feet and legs or to rump angle.

Results of stepwise regression techniques used to evaluate the ability of STA of linear type to predict PTA for SCS are in Table 4. Because higher held udders should remain cleaner and drier, udder depth was expected to have been the best predictor of PTA for SCS. However, STA for fore udder attachment explained the most variation. In this study, STA for udder depth and fore udder attachment were highly correlated (.84), and STA for udder depth was most predictive of PTA for SCS if STA for fore udder attachment was excluded from the model (Table 5). Sieber et al. (10) examined linear type scores by factor analysis and found udder depth and fore udder attachment to be part of the same explanatory factor.

The STA for thurl width, strength, dairy form, body depth, and rump angle were also part of the stepwise model to predict PTA for SCS (Table 4) but contributed far less to the $R^2$ of the model. If STA for fore udder attachment was excluded from the prediction model (Table 5), STA for stature was more predictive than STA for strength, and STA for front teat placement entered the model but was removed later. The order in which STA for dairy form, body depth, and rump angle entered the prediction model also was altered. If STA for udder depth and STA for fore udder attachment were both excluded from model consideration (Table 6), STA for front teat placement became the most predictive trait. The $R^2$ was much smaller (.042) than if STA for fore udder attachment (.098) or STA for udder depth (.078) was the most predictive trait included. The STA for rear udder width entered the stepwise model at step 6.

Compared with results in Table 4, consideration of quadratic terms for STA of type traits did not contribute greatly to prediction of PTA for SCS. Quadratic terms for udder depth, fore udder attachment, and dairy form entered at steps 4, 5, and 6. Although the quadratic terms entered the model at a higher level of significance, model $R^2$ was actually reduced after six steps. When analyzed separately for each STA, quadratic effects on PTA for SCS were

TABLE 6. Stepwise regression of PTA for somatic cell score on standardized transmitting abilities of 12 linear type traits (fore udder attachment and udder depth excluded).

| Step | Type trait entered | Model $R^2$ |
|---|---|---|
| 1 | Front teat placement | .042 |
| 2 | Thurl width | .068 |
| 3 | Dairy form | .080 |
| 4 | Strength | .089 |
| 5 | Body depth | .109 |
| 6 | Rear udder width | .120 |
| 7 | Stature | .123 |

TABLE 7. Stepwise regression of PTA for somatic cell score on standardized transmitting abilities (STA) for linear type traits and PTA for milk yield.

| Step | Trait entered | Model $R^2$ |
|---|---|---|
| 1 | Fore udder attachment | .098 |
| 2 | Thurl width | .108 |
| 3 | Strength | .119 |
| 4 | Milk yield | .123 |
| 5 | Rump angle | .127 |

important only for STA for udder cleft ($P < .03$) and udder depth ($P < .02$), and quadratic regression coefficients were positive.

Because the predictive ability of dairy form might result from the positive correlation of PTA for milk yield with PTA for SCS (.13) and with STA for dairy form (.45), PTA for milk yield was included along with STA for all 14 linear type traits in a separate stepwise regression analysis. Results in Table 7 corresponded well with those in Table 4, except that PTA for milk yield replaced STA for dairy form in the model. In addition, body depth no longer entered the model at the .15 level of significance.

## CONCLUSIONS

Selection for some linear type traits already may be assisting in selection for udder health as measured by SCS. Sires with daughters that had lower SCS also had daughters with higher held udders, more snugly attached fore udders, and more closely placed front teats. Holstein bulls with the lowest PTA for SCS had more favorable STA for most type traits, but especially for udder traits. The STA for fore udder attachment and udder depth explained the most variation in bulls' PTA for SCS, but low $R^2$ suggests that type trait profiles should not act as complete substitutes for selecting lower PTA for SCS. Selection goals that include higher, more firmly attached udders and lower SCS are compatible.

## ACKNOWLEDGMENTS

Appreciation is expressed to Tom Lawlor and the Holstein Association for providing the linear type evaluations of Holstein bulls and to Gary Rogers for helpful suggestions. The cooperation of the US dairy industry in supplying SCS, production, and pedigree data through the National Cooperative Dairy Herd Improvement Program also is appreciated.

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