INTERPRETIVE SUMMARY

Genetic evaluation of rear legs (rear view) for Brown Swiss and Guernseys. *By Wiggans et al.,* page 000. Improvement in structural soundness is important to dairy producers because lame animals may produce less milk or be less fertile. The Brown Swiss Association and the American Guernsey Association began scoring rear legs (rear view) in 2004. Heritability estimates for this trait were 10% for Brown Swiss and 8% for Guernsey. Moderate correlations were found with other linear type traits. Evaluations were first released in May 2006.

EVALUATION OF REAR LEGS (REAR VIEW)

Genetic Parameters and Evaluation of Rear Legs (Rear View) for Brown Swiss and Guernseys

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ABSTRACT

Genetic parameters for rear legs (rear view) (RLRV) and 15 current linear type traits of Brown Swiss and Guernsey dairy cattle were estimated. The Brown Swiss Cattle Breeders' Association of the USA and the American Guernsey Association began scoring RLRV in 2004. For Brown Swiss, 8,502 records were available for 7,676 cows in 417 herds; Guernsey data included 5,437 records for 4,749 cows in 229 herds. Nine unknown-parent groups were defined for each breed, each with 2 birth years. The model included fixed effects for interaction of herd, appraisal date, and parity; appraisal age within parity; and lactation stage within parity and random effects for animal, permanent environment, and residual error. The multitrait analysis for RLRV and the 15 linear type traits used canonical transformation, multiple diagonalization, and a decelerated expectation-maximization REML algorithm. For Brown Swiss, heritability was .102 for RLRV and ranged from 0.099 for rear legs (side view) to 0.453 for stature. For Guernseys, heritability ranged from 0.078 for RLRV to 0.428 for stature. For Brown Swiss, highest genetic correlation with RLRV was 0.71 for rear udder width; most negative correlation was −0.19 with rump angle. For Guernseys, highest genetic correlations with RLRV were 0.43 for rear udder width and 0.42 for body depth; most negative correlation was −0.46 with rear legs (side view). With heritability near .10, RLRV should be useful in selection for improved locomotion. Release of genetic evaluations for RLRV began in May 2006 for Brown Swiss and Guernseys.

(**Key words:** rear legs, type trait, genetic evaluation)

INTRODUCTION

Mobility is a growing concern in today's intensive dairy environments, both for confinement operations where cows are on slippery concrete for most of the time and for grazing situations where cows are required to walk long distances. Lameness is the third most likely cause of involuntary culling after fertility and mastitis (National Animal Health Monitoring System, 2002). Boettcher et al. (1998) suggested that selection for rear legs (rear view) (**RLRV**) may help to reduce locomotion problems because of its relatively high genetic correlation with clinical lameness.

The Brown Swiss Cattle Breeders' Association of the USA (**BSA**; Beloit, WI) and the American Guernsey Association (**AGA**; Reynoldsburg, OH) added the trait rear legs (rear view) (**RLRV**) to their linear appraisal programs in 2004 to address mobility problems (Neitzel, 2004; S. Johnson, AGA, Reynoldsburg, OH, personal communication). The BSA began scoring RLRV to detect more easily bulls that sire daughters with mobility problems caused by rear leg set and low herd life as well as daughters with infertility caused by locomotion problems. The AGA identified RLRV as potentially more useful than rear legs (side view) in detecting mobility problems that impact productive life. Holstein Association USA (Brattleboro, VT) has included RLRV in its feet-and-legs composite since January 1996 (Holstein Association USA, 1996).

The BSA scores RLRV from 1 to 9. A score of 1 indicates a rear leg that is severely hocked in and toed out; a score of 9 indicates legs that are directly perpendicular to the ground and may be toed in. The AGA scores RLRV from 1 to 50. The difference in scoring scale is also present for all linear traits that are appraised by these two breed associations. The Brown

Swiss 9-point scale was implemented because of its slightly greater accuracy than a 50-point scale (R. R. Neitzel, unpublished data) and to accommodate rapid data entry into handheld computers (Neitzel, 2003)). For genetic evaluation, Brown Swiss scores on the 9-point scale are multiplied by 5 to combine them with historical data on the 50-point scale.

Although feet and leg traits tend to little relationship to actual profit, a positive linear relationship has been found between those traits and survival and functional herd life (Norman et al., 1996; Pérez-Cabal and Alenda, 2002). In general, a score for RLRV that is slightly straighter than mid-range is preferred (Fatehi et al., 2003;) because of a positive relationship between RLRV and productive life (Rogers, 1996); Tsuruta et al., 2005), but extremes are not desirable (Caraviello et al., 2004; Sewalem et al., 2004). Although no direct link appears to exist between RLRV and fertility or milk production, a low-scoring animal may have greater fertility problems and lower milk production because of reduced mobility (Shapiro and Swanson, 1991; Boettcher et al. 1998). Several studies found low heritability estimates for RLRV, with a range of 0.09 to 0.12 (Fuerst-Waltl et al., 1998; DeGroot et al., 2002; Reinhardt et al., 2005). Holstein Association USA uses a heritability of 0.11 in its evaluation of RLRV and places 37% emphasis on RLRV in the feet-and-legs composite (Holstein Association USA, 1996).

A majority of participants in the International Bull Evaluation Service (**Interbull**, Uppsala, Sweden) collect and use RLRV in their national evaluations for the Holstein breed; few use RLRV for evaluation of conformation of other breeds (International Bull Evaluation Service, 2006a). Only New Zealand and the Czech Republic do not include an RLRV component for type evaluation of Holsteins (International Bull Evaluation Service, 2006b). Jersey and

Ayrshire are the colored breeds that are most frequently evaluated for RLRV internationally. Although Interbull does not currently collect Brown Swiss RLRV data for international genetic evaluation, Canada, Germany-Austria, France, the Netherlands, Switzerland, and the US provide an overall feet-and-legs composite. For Guernseys, Australia, Canada, the United Kingdom, and the US contribute a feet-and-legs composite, and Australia and Canada also provide RLRV as an individual trait (International Bull Evaluation Service, 2006b).

A multitrait animal model (Gengler et al., 1997a, 1997b, 1999) has been used to calculate type evaluations for Brown Swiss and Guernseys since February 1998. The purpose of this study was to estimate genetic parameters for RLRV and to develop a genetic evaluation system.

MATERIALS AND METHODS

Data

Brown Swiss data were 8,502 records from 2004 through March 2006 for 7,676 cows in 417 herds. Scores were assigned by 16 appraisers; 2 appraisers contributed 43% of the appraisals. Pedigree data (23,353 records) included ancestors born during 1985 and later. Appraisal scores were multiplied by 5 to make them compatible with previously recorded type traits that were scored from 1 to 50. The 865 sires averaged 8.9 daughters with appraisals. Scores were required for each of the 15 other linear type traits.

Guernsey data were 5,437 records from October 2004 through March 2006 (1 herd appraisal from October 2002 also was included) for 4,749 cows in 229 herds. Scores were assigned by 19 appraisers; 3 appraisers contributed 61% of the appraisals. Pedigree data

(17,827 records) included ancestors born during 1985 and later. The 603 sires averaged 7.9 daughters with appraisals. For both breeds, 9 unknown-parent groups were defined, each with 2 birth years.

Figure 1 shows the frequency of RLRV scores for both breeds. Brown Swiss cattle tended to have higher scores, higher median score, and greater skew from a normal distribution than did Guernseys. The difference reflects differences in breed programs as well as biological differences. Because the majority of Brown Swiss cows have fairly straight legs, they intentionally are scored as 7 (rather than 5) so that higher scores (8 and 9) will be assigned to cows that toe in (R. R. Neitzel, unpublished data).

Estimation of Variance Components

Variance components were estimated with MTC (multitrait REML estimation of variance components program by canonical transformation with support for multiple random effects; I. Misztal, University of Georgia, Athens, personal communication); calculations were as described by Gengler et al. (1997a, 1997b, 1999) using expectation-maximization REML and canonical transformation as described in Misztal (1994) and Wiggans et al. (2004). The model included fixed effects for interaction of herd, appraisal date, and parity (first or later); appraisal age (2-mo group; more months included for youngest and oldest ages) within parity (29 levels for each breed); and lactation stage (1 through 8 as assigned by breed association) within parity (1, 2, and ≥3) and random effects for animal, permanent environment, and residual. The expectation-maximization REML algorithms used previously (e.g., Misztal et al., 1995) were modified because they gave unstable estimates and poor convergence in other work with small data sets (N. Gengler, unpublished data). Estimates of variance components also tended to move quickly beyond acceptable limits. The modification was a deceleration, which was implemented by halving the updating steps of variance components.

Calculation of Evaluations

The evaluations for linear type traits used a multitrait model. As done routinely for Brown Swiss and Guernsey type evaluations (Gengler et al., 1999), an effect for interaction of herd and sire (945 levels for Brown Swiss; 586 levels for Guernseys) was included in the model (in addition to the effects included for variance-component estimation) to restrict impact of bulls with evaluations based on daughters in only 1 herd, and 40% of the permanent environmental variance was assigned. Missing values were allowed for linear traits other than RLRV. Data edits for routine national type evaluations were imposed (Animal Improvement Programs Laboratory, 2005). For Brown Swiss, scores at ages beyond 68 mo and records for cows that were not scored during their first 2 lactations were excluded, which resulted in 6,407 records for calculation of evaluations; all Guernsey data were included because Guernsey does not require appraisal in early parities.

A canonical transformation was applied to minimize computational demands. Because some traits have missing values, the technique of Ducrocq and Besbes (1993) was used to estimate missing values at each iteration so that the solutions for all effects would not be affected by the missing values. Initial efforts with this approach to integrate RLRV data with historical data starting with appraisals in 1980 did not converge satisfactorily, probably because RLRV observations had to be estimated for the first 23 yr of data. As a result, type evaluations were calculated in 2 steps. First, the current evaluation system for linear type traits was used unchanged for all traits except RLRV. Second, RLRV was included in a multitrait evaluation using only the observations with RLRV. This approach gave the RLRV evaluation the benefit of information from correlated traits but did not require estimation of many missing values. No adjustment for heterogeneous variance was done for the second set of evaluations to minimize the computations required and because stability of such an adjustment cannot be guaranteed for limited time periods. The overall approach was a compromise between optimal use of correlated information and feasibility.

RESULTS AND DISCUSSION

Variance Components

Estimates of variance components converged and were stable with the deceleration algorithm. The number of iteration rounds to convergence tended to be much larger (>400) than for previous computations (<200) of similar variance components (G. R. Wiggans, unpublished data). The delay in convergence was not merely a consequence of deceleration, as the evaluation system could not converge without deceleration. The application of the deceleration algorithm did not overly extend the computing time that was required for estimation of variance components because the data sets were small.

Estimated standard deviations (**SD**) and heritabilities for the 15 linear traits that are currently evaluated and RLRV are in Table 1. Guernsey SD were slightly larger than Brown Swiss SD; differences could be the result of different breed scoring systems. The largest SD was for fore udder attachment (7.6, Brown Swiss; 8.7, Guernseys). The smallest SD was for thurl width of Brown Swiss (5.5) and body depth of Guernseys (6.6).

Heritabilities for the records that included RLRV data (Table 1) ranged from 0.099 for rear legs (side view) to 0.453 for stature for Brown Swiss and from 0.078 for RLRV to 0.428 for stature for Guernseys. Heritability for RLRV was 0.102 for Brown Swiss. Fuerst-Waltl et al. (1998), DeGroot et al. (2002), and Reinhardt et al., 2005 reported RLRV heritabilities of <0.12 for Holsteins. McDaniel (1997) suggested that low heritability estimates for RLRV may result from variation in trait measurement rather than lack of genetic variation and that larger underlying differences may be masked by discrepancies in scoring. Other traits with low heritability estimates (<0.12) from records with RLRV data (Table 1) were rear legs (side view) for Brown Swiss and foot angle for Brown Swiss and Guernseys. Heritabilities used for current evaluations (Wiggans, 2004) are 0.18 for rear legs (side view) for Brown Swiss and 0.13 and 0.10 for Brown Swiss and Guernsey foot angle, respectively.

Differences between current heritabilities (Wiggans, 2004) and those from records with RLRV data also are presented in Table 1. Heritabilities averaged 0.030 lower for Brown Swiss and 0.021 lower for Guernseys for the 15 currently evaluated traits and ranged from 0.110 lower for Guernsey rump angle to 0.045 higher for Guernsey fore udder attachment. The change in heritabilities may reflect sampling errors from the limited amount of data, especially for dams because of the short period of data collection, or changes in parameters over time.

Phenotypic and genetic correlations of the 15 currently evaluated linear type traits with RLRV are in Table 2. For Brown Swiss, rear udder width had the highest genetic correlation

(0.71) with RLRV; rump angle had the most negative correlation (−0.19). For Guernseys, the highest genetic correlations with RLRV were 0.43 for rear udder width and 0.42 for body depth, and the most negative correlation was −0.46 with rear legs (side view). The relatively high genetic correlation of RLRV with rear udder width and moderate correlations with rear udder height (0.31, Brown Swiss; 0.22, Guernseys) may suggest a link between udder fullness and RLRV. Short et al. (1991) reported a genetic correlation with RLRV of 0.35 for rear udder width and 0.29 for rear udder height for Holsteins and noted: "Amount of milk in the rear udder influences the degree to which cows hock-in; wide, full udders cause the hocks to be farther apart." The fullness of the udder may cause rear legs to be set out more and reduce how much the legs are hocked in and toed out. A uniform time for scoring (e.g., just prior or after milking) could be implemented to alleviate bias caused by fullness of the udder. However, cows that would have had lower RLRV scores if their udders had been less full likely would still have mobility problems and would score poorly for RLRV after dry off. The model effect for lactation stage also should help to eliminate bias due to udder fullness.

Evaluations

Evaluation statistics are in Table 3 for PTA based on a 50-point scale. Although heritability for Guernseys was lower than for Brown Swiss, SD of evaluations were greater, which reflects the larger variance of RLRV for Guernseys; phenotypic SD (Table 1) also was larger for Guernseys than for Brown Swiss. The greater variability in Guernsey RLRV scores may have resulted from the different scales used in scoring. Mean PTA were close to 0 because birth years of cows with data are close to the base year of 2000 and little genetic trend appears to have occurred.

CONCLUSIONS

Inclusion of RLRV in appraisal programs allows breeders to obtain a better description of the components of locomotion. The cows that tend to score higher for RLRV (i.e., straighter legs from the rear) also tend to have a steeper foot angle and straighter rear legs when viewed from the side. A cow with straighter rear legs is expected to walk with greater forward and less sideways motion, which would reduce udder contact and damage (and associated SCS) as well as joint impact and injury, and to be able to stand securely on any surface, which may result in better heat detection and higher fertility.

Genetic evaluations for Brown Swiss and Guernsey RLRV were released by USDA in May 2006. Because of the importance of locomotion traits, those evaluations should be useful in selection programs. Although RLRV had a relatively low heritability compared with other evaluated linear type traits, it is likely to be included in the feet-and-legs composite that is used for calculation of USDA-DHIA economic indexes for lifetime merit.

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Table 1. Estimated total SD (square root of sum of residual, genetic, and permanent environmental variances), heritabilities, and differences between heritabilities for 16 linear type traits by breed

	Brown Swiss				Guernsey			
		Heritability				Heritability		
Trait	Total SD	Records with data for rear legs (rear view)	Current[1]	Difference[2]	Total SD	Records with data for rear legs (rear view)	Current	Difference
Stature	6.7	0.453	0.432	0.021	8.6	0.428	0.488	−0.060
Strength	6.5	0.145	0.198	−0.053	6.9	0.190	0.225	−0.035
Dairy form	7.3	0.155	0.182	−0.027	7.9	0.206	0.284	−0.078
Foot angle	6.6	0.119	0.130	0.011	6.6	0.085	0.096	−0.011
Rear legs (side view)	6.1	0.099	0.181	−0.082	6.8	0.151	0.157	−0.006
Body depth	6.5	0.201	0.249	−0.048	6.6	0.247	0.320	−0.073
Rump angle	6.4	0.212	0.274	−0.062	7.2	0.303	0.413	−0.110
Thurl width	5.5	0.151	0.176	−0.025	7.0	0.248	0.286	−0.038
Fore udder attachment	7.6	0.210	0.221	−0.011	8.7	0.333	0.288	0.045
Rear udder height	6.5	0.230	0.215	0.015	7.3	0.288	0.281	0.007
Rear udder width	6.2	0.144	0.190	−0.046	7.2	0.266	0.278	−0.012
Udder depth	5.6	0.329	0.338	−0.009	6.9	0.397	0.395	0.002
Udder cleft	7.1	0.177	0.216	−0.039	7.6	0.210	0.210	0.000
Front teat placement	6.7	0.209	0.271	−0.062	7.5	0.343	0.310	0.033
Teat length	7.1	0.308	0.336	−0.028	6.9	0.358	0.340	0.018
Rear legs (rear view)	5.8	0.102	—	—	7.4	0.078	—	—

[1]Wiggans et al. (2004).

[2]Difference = heritability estimated from records with data for rear legs (rear view) − current heritability.

Table 2. Estimated phenotypic and genetic correlations of 15 linear type traits with rear legs (rear view) by breed

	Brown Swiss		Guernsey	
Trait	Phenotypic	Genetic	Phenotypic	Genetic
Stature	0.07	0.15	0.04	0.18
Strength	0.09	0.49	0.12	0.30
Dairy form	0.07	0.44	0.08	0.34
Foot angle	0.19	0.19	0.21	0.31
Rear legs (side view)	−0.16	−0.11	−0.19	−0.46
Body depth	0.11	0.40	0.08	0.42
Rump angle	−0.03	−0.19	−0.06	−0.08
Thurl width	0.09	0.47	0.06	0.16
Fore udder attachment	0.10	0.24	0.06	0.06
Rear udder height	0.14	0.31	0.11	0.22
Rear udder width	0.20	0.71	0.23	0.43
Udder depth	0.03	0.01	−0.01	−0.11
Udder cleft	0.05	0.09	0.03	−0.04
Front teat placement	0.05	0.19	0.03	0.19
Teat length	0.02	0.04	0.02	0.13

Table 3. Descriptive statistics for evaluations[1] for rear legs (rear view) for cows and for bulls with ≥5 daughters

	Cows		Bulls with ≥5 daughters	
Statistic	Brown Swiss	Guernsey	Brown Swiss	Guernsey
Animals, no.	5,709	4,749	228	213
Daughters, no.	—	—	20.9	19.0
Herds, no.	—	—	12.8	10.4
PTA				
Mean	0.01	0.08	0.02	0.07
Minimum	−1.50	−2.70	−1.20	−1.70
Maximum	1.30	2.60	1.30	2.20
SD	0.39	0.52	0.43	0.61
Reliability, %	32.9	29.9	49.6	44.7

[1]Evaluations are PTA based on a 50-point scale.

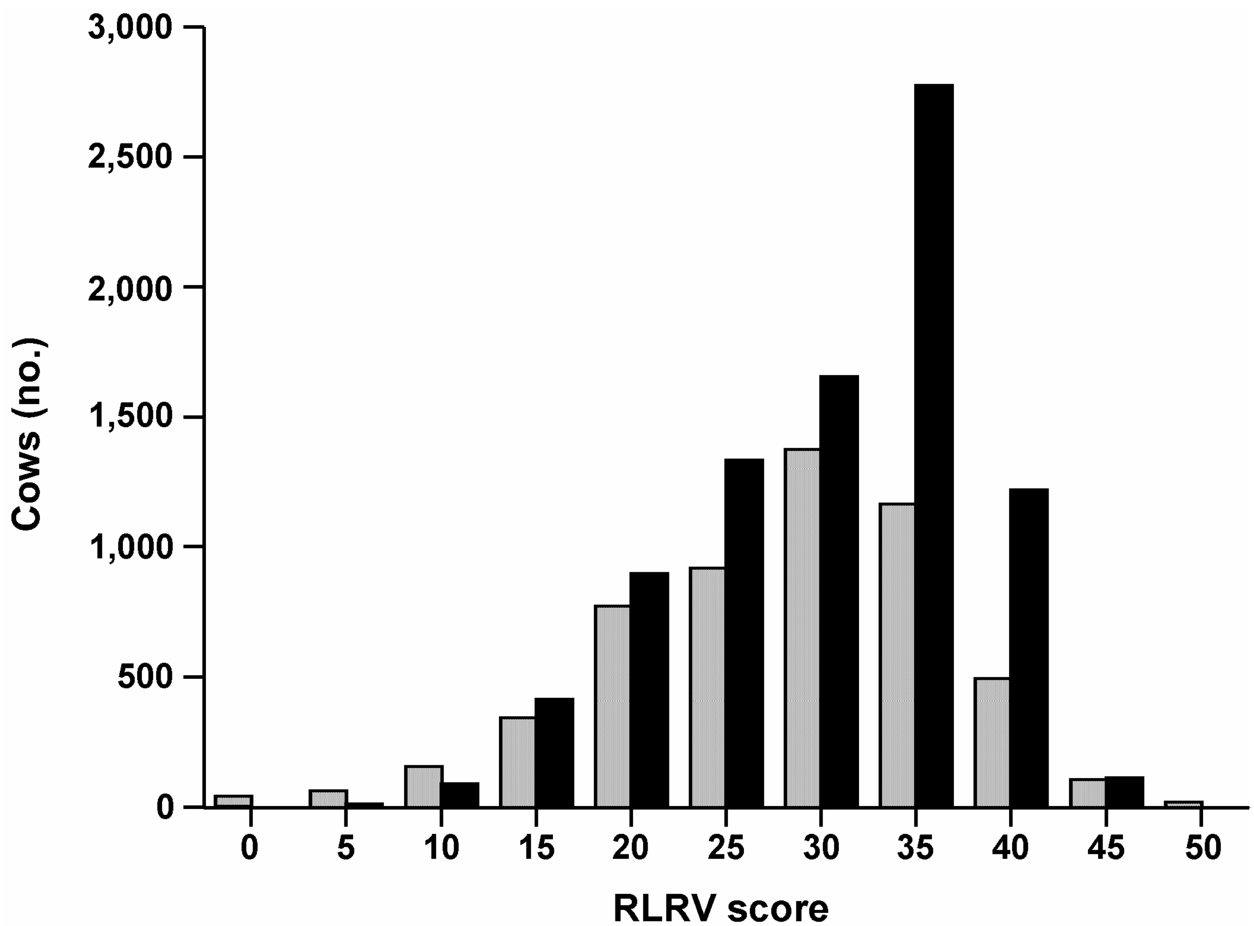

Figure 1. Frequency of rear legs (rear view) (RLRV) scores for Brown Swiss (■) and Guernseys (▩). Original Brown Swiss scores of 1 through 9 were multiplied by 5; Guernsey frequencies were grouped as 0 = 1 to 2, 5 = 3 to 7, 10 = 8 to 12, … 45 = 43 to 47, 50 = 48 to 50.