Consistency of International Genetic Evaluations of Holstein Bulls

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ABSTRACT

International genetic evaluations from August 1995 and February 1996 for Holstein bulls from Canada, France, Germany, Italy, The Netherlands, and the US were evaluated for consistency across time. Mean evaluations, expressed on a US basis, were unchanged for US bulls; evaluations for bulls from France, Germany, Italy, and The Netherlands increased about 14 kg for milk and 0.4 kg for fat and protein. Mean genetic merit of US parents of bulls sampled in Canada, France, Germany, The Netherlands, and the US overestimated bull merit. Solutions for country of bull generally were not different for other countries relative to the US; however, evaluations for German and Netherlands bulls were higher than evaluations for US bulls with the same parent merit. French bulls that were full brothers to US bulls had higher evaluations for milk and protein, regardless of country of evaluation. Intercepts for conversion equations to a US basis increased by birth year and decreased for conversions from a US basis. Future international evaluations generally were predicted more accurately by prior international evaluations than by more recently converted national evaluations; however, converted evaluations with substantial increases in data could be better predictors, depending on country. The continued use of the latest international evaluations is recommended. Improvements in methodology that increase the consistency of evaluations across time and location may be possible. Alternatively, users may need to accept some uncertainty and error in international evaluations because of limitations in available data and methodology.
(**Key words**: breeding, genetics, international evaluation)

Abbreviation key: **INTERBULL** = International Bull Evaluation Service, **PA** = parent average.

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INTRODUCTION

In 1994, the International Bull Evaluation Service (**INTERBULL**) established the INTERBULL Centre in Uppsala, Sweden and began to provide international evaluations for dairy sires. This service is financed by the countries that receive the results; most of these countries also provide the national bull evaluations that are input data for the INTERBULL evaluations. The first routine results were released in August 1994 for data on Ayrshire and Holstein bulls from the Nordic countries (2). The procedure used was a linear model combination of evaluation and pedigree data that had been suggested by Schaeffer (4), except that deregressed evaluations (6) were used instead of daughter yield deviations. This procedure assumed that genetic correlations among all countries were at unity. The multitrait across-country evaluation (or MACE) method of Schaeffer (5), which allows genetic correlations of <1.0 among countries to be included, was used for routine INTERBULL evaluations beginning with February 1995 evaluations; however, all genetic correlations were assumed to be 0.995 (1). Genetic correlations that were derived from submitted data were determined (7) and used for August 1995 and February 1996 evaluations.

One desirable characteristic of genetic evaluations is consistency (or stability) over time. The INTERBULL evaluations for Holsteins in August 1995 and February 1996 were calculated with the methodology of Schaeffer (5). Two countries (Great Britain and Switzerland) were added in February 1996, and minor changes were made to estimates of sire genetic variances and genetic correlations. Except for changes to the base, expected changes between evaluations should only be those caused by the addition of data; mean evaluations for groups of bulls in both evaluations should be stable.

The routine INTERBULL evaluations are a service that is paid for by recipients of the evaluations, and each country determines what use to make of the results. Typically, the INTERBULL results are ac-

cepted as official for foreign bulls without a national evaluation above a designated reliability. Although the policy of a country may be to use INTERBULL results for most foreign bulls, a question arises when a new foreign evaluation becomes available and contains more data than were used in the most recent INTERBULL evaluation. In this situation, should conversion equations be applied to the new foreign evaluations that contain additional data for daughters in the home country, or should the older INTERBULL evaluations that contain data for daughters in other countries continue to be used? That decision depends on which approach best predicts the next INTERBULL results.

The objective of this study was to examine the consistency of the February 1996 INTERBULL evaluation for Holsteins. The four parts of the study were 1) examination of changes in INTERBULL evaluations over time by country, 2) analysis of deviation of evaluations from mean genetic merit of parents by country, 3) calculation of conversion equations by birth year, and 4) determination of accuracy of converted national evaluations for predicting future INTERBULL evaluations.

MATERIALS AND METHODS

Data

Data included August 1995 and February 1996 INTERBULL evaluations for milk, fat, and protein for Holstein bulls from Canada, France, Germany, Italy, The Netherlands, and the US. Pedigree data were obtained from national files for Canada, France, Germany, The Netherlands, and the US. Any reference to country of bull indicates the country of most daughters for the INTERBULL evaluation. Evaluations on a US basis are reported in kilograms of PTA; evaluations on the bases of other countries are reported in kilograms of EBV.

Changes in INTERBULL Evaluations

August 1995 and February 1996 INTERBULL evaluations for milk, fat, and protein were compared by country for Holstein bulls from France, Germany, Italy, The Netherlands, and the US. Canadian bulls were not included because of the many changes in procedures of the Canadian national evaluation between the August and February evaluations. Because no substantive changes in procedure occurred for the national or INTERBULL evaluations of other countries, individual bulls with added data might have changed, but groups of bulls (such as from an individual country) should have remained stable. All evaluations were expressed on a US basis (kilograms of PTA).

Bulls with the Same Merit

Bulls of equal genetic merit are expected to have the same evaluations, regardless of where their daughters are located, even across countries, except for the effect of genetic correlations among countries. The most similar genetic background is identical twins. However, because those are rare, especially across countries, full brothers and bulls with US parents and US parent averages (**PA**) were used. Parent average is the mean PTA of the parents. Dam identification was obtained from national evaluation data because this identification was not included in INTERBULL evaluation data. The US evaluations for sires and dams were used to create PA on the US basis for all bulls. Because of the feedback between son and parents in an animal model system (8), US PA are expected to be more similar to evaluations of sons from the US than those from other countries, especially for individual bulls.

Theoretically, groups of bulls with the same parents (or PA) should have similar INTERBULL evaluations, regardless of country of sampling. Three analyses of bulls with US parents were undertaken to check that assumption. In the first analysis, evaluations for milk, fat, and protein yields on a US basis had PA subtracted to provide an estimate of Mendelian sampling, which should be 0 (or at least equal across countries). The second analysis fit a model with country of bull and PA for protein to February 1996 INTERBULL evaluations for protein yield from each country:

$$y = \text{country} + \text{US PA} + \text{error}$$

where y is evaluation on the basis of a particular country. Bulls were from Canada, France, Germany, The Netherlands, and the US. Italian bulls that had both parents from the US were too few to be included. Bulls were born during 1985 or later. Reliability for PA was required to be ≥35%. The first analysis was essentially the same as the second analysis on a US basis except that the coefficient of US PA was forced to 1.

The third analysis used a subset of the data for the second analysis that consisted of 464 bulls in 145 full-brother families with members in both the US and France. A previous study (3) had shown that France had the most full-brother families in common with

TABLE 1. Changes from August 1995 to February 1996 International Bull Evaluation Service evaluations on a US basis for all Holstein bulls from different countries and the top 50 bulls for protein yield in August from each country.

Trait	France	Germany	Italy	The Netherlands	US
All bulls from each country					
Milk, kg	12	16	14	14	3
Fat, kg	0.3	0.4	0.6	0.3	0.1
Protein, kg	0.3	0.4	0.4	0.4	0.1
Bulls, no.	9873	7687	2264	5610	15,370
Top 50 bulls for protein from each country					
Milk, kg	–15	–98	–17	8	–89
Fat, kg	–0.5	–3.3	–0.1	–0.3	–2.0
Protein, kg	–0.4	–3.3	0.3	0.1	–2.6

the US. Solutions for 258 French bulls relative to their 206 US full brothers were obtained from

$$y = \text{country} + \text{family} + \text{error}$$

where y is February 1996 INTERBULL evaluation for protein yield, country was France or the US, and family (sire-dam combination) was absorbed.

Conversions by Year

Bulls of a given genetic merit should have that same merit, regardless of when the bulls were used as a sire within a country or across countries, unless heterosis is affecting a population that is being upgraded and is not accounted for in the model. One way of examining this assumption relative to INTERBULL evaluations is to determine whether conversion equations differ by bull birth year. Conversion equations were computed by the least squares regression of the evaluation on a US basis on the evaluation on the basis of the exporting country. As is the practice with calculation of conversion equations by the INTERBULL Centre, included bulls were initially sampled in the exporting country. Information was not directly available to determine initial country of sampling; therefore, the country that had the most daughters was used.

Accuracy of National Evaluations for Predicting INTERBULL Evaluations

Shortly after the release of August 1995 results from the INTERBULL Centre, Germany and The Netherlands released national evaluations based on data that were more recent than those used for the INTERBULL evaluations. Bulls with daughters only from those countries were converted to a US basis with the conversion equations developed from INTERBULL results. Those converted evaluations were compared with August 1995 INTERBULL evaluations as predictors of February 1996 INTERBULL evaluations to determine which evaluations were the most accurate predictors.

RESULTS

Changes in INTERBULL Evaluations

As shown in Table 1, mean evaluations on a US basis were similar in August 1995 and February 1996 for bulls from each country. Evaluations increased slightly more for European bulls; evaluations for US bulls were essentially unchanged. For the top 50 bulls from each country, based on August 1995 INTERBULL evaluations for protein yield, evaluations for bulls from The Netherlands changed little, but evaluations for bulls from other countries tended to decrease; evaluations for US and German bulls dropped substantially. Although the top US bulls lost rank from August 1995 to February 1996, a comparison of national evaluations for the top 50 bulls from each country (not shown) showed results that were similar to those in Table 1. Thus, the changes for top bulls reflected the changes in national evaluations on the original scale and were not due to the INTERBULL procedure.

Bulls with the Same Parent Merit

Bulls with the same PA would be expected to have similar mean values for estimated genetic merit, regardless of the country of use when evaluations were expressed on a common scale; lack of equality results from genetic correlations between countries of <1. Even if PA overestimated bull merit, the differ-

TABLE 2. Mean differences between February 1996 International Bull Evaluation Service evaluations and parent averages on a US basis for Holstein bulls.

Trait	Canada	France	Germany	The Netherlands	US
Milk, kg	–18	–11	13	9	–44
Fat, kg	–2.1	–2.9	–1.9	–1.5	–1.9
Protein, kg	–1.2	–1.1	–0.4	–0.9	–1.4
Bulls, no.	252	1241	430	765	7207

ence between evaluation and PA should be similar across countries and should favor bulls with daughters in the country of that scale. As shown in Table 2, INTERBULL evaluations generally were lower than PA, especially for US bulls for milk and protein yields, although US bulls would be expected to be favored. For fat yield, the largest discrepancy between PA and INTERBULL evaluations was for French bulls.

Table 3 shows the solutions for each country relative to US solutions from the model that included country and PA of bull. On a US basis, differences between countries, except for Canada, were generally small and were similar to mean differences for protein evaluations in Table 2 relative to the US. Although genetic merit of parents was accounted for in the model, evaluations for US bulls tended to be lower than those from France, Germany, and The Netherlands and slightly higher than those from Canada on a US basis. Relative to US bulls and accounting for PA, evaluations for Netherlands bulls were higher on French ($P = 0.06$) and US ($P < 0.01$) bases; evaluations for German bulls were lower ($P < 0.01$) on a German basis and higher ($P < 0.01$) on a US basis. This contrast may be due to differences in genetic correlations between countries; the genetic correlation is lowest between Germany and the US. The model R^2 were 0.41 for Canada, 0.45 for France, 0.33 for Germany, 0.44 for The Netherlands, and 0.53 for the US. Addition of a quadratic term for PA for protein yield increased R^2 by less than 0.001.

Bulls with the same PA are expected to have the same estimated genetic merit if their dams received either no preferential treatment or equal preferential treatment. For bulls that are full brothers, preferential treatment of dams is not a concern. When a number of full-brother families in common between the US and France were compared, solutions for French bulls were higher ($P < 0.05$) than for the US full brothers for milk and protein yields, expressed on the basis of either country (Table 4). This bias against US bulls was about the same for either scale when units were considered.

Conversions by Year

The intercepts and regression coefficients for conversion of protein yield evaluations to a US basis are in Table 5 by birth year. The regression coefficients for Canada, France, and Germany fluctuated without a directional trend, which suggested sampling variation; however, there was an increase for Italy and The Netherlands. Intercepts for each country increased with later birth years. Birth year had a positive linear

TABLE 3. Solutions for country of bull for February 1996 International Bull Evaluation Service evaluations for protein yield on the basis[1] of each country relative to US bulls from a model that included country and parent average for Holstein bulls.

	Country of bull				
Country of scale	Canada	France	Germany	The Netherlands	US
Canada	0.0	0.3	–0.6	–0.1	0.0
France	0.1	0.1	0.2	0.4	0.0
Germany	–0.1	0.0	–0.8**	0.0	0.0
The Netherlands	0.0	0.2	0.1	0.2	0.0
US	–0.2	0.2	0.8**	0.6**	0.0

[1]Solutions are reported in kilograms of EBV for all countries except US; US solutions reported in kilograms of PTA.

**Significantly different from US bulls ($P < 0.01$).

TABLE 4. Solutions for 258 French full brothers for February 1996 International Bull Evaluation Service evaluations on the basis[1] of each country relative to 206 US full brothers from a model that included country and 145 bull families for Holstein bulls.

	Base	
Trait	France	US
Milk	97*	55*
Fat	1.1	0.7
Protein	2.4*	1.5*

[1]Solutions are reported in kilograms of EBV for France and kilograms of PTA for the US.

*French bulls significantly different from US bulls ($P < 0.05$).

effect ($P < 0.01$) in prediction of a US evaluation from evaluations in each country. Prediction equations of evaluations from other countries from a US evaluation (not shown) all had negative effects for year ($P < 0.01$). Again, the yearly regression coefficients were similar, but the intercepts showed a negative trend. Yearly equations for converting protein evaluations from The Netherlands to France (not shown) also showed increases in both intercepts and regressions. However, equations from France to The Netherlands (not shown) did not show trends with birth year. Theoretical regression coefficients are the ratio of sire genetic standard deviations in two countries times the genetic correlation between the countries. The regression coefficients proposed by the INTERBULL Centre were less favorable to the US than were theoretical coefficients (not shown), regardless of conversion direction (i.e., to or from the US). However, the coefficients for 1990 (Table 5) generally were similar to theoretical coefficients except for The Netherlands, for which the theoretical coefficients were much lower.

Accuracy of National Evaluations for Predicting INTERBULL Evaluations

August 1995 INTERBULL evaluations were better predictors of February 1996 INTERBULL evaluations on a US basis than were conversions from interim national evaluations as measured by mean difference, standard deviation of difference, or mean absolute difference between evaluations (Table 6). Results (not shown) were similar when only bulls born since 1985 were included. Because only bulls that had a large increase in daughter data would be expected to have more accurate converted evaluations, differences also were compared for bulls with a ≥25% or ≥50% increase in daughter numbers for the interim national evaluation. For bulls with a ≥25% increase in daughters, the August 1995 INTERBULL evaluations were superior to converted national evaluations of Netherlands bulls for predicting February 1996 INTERBULL evaluations. For German bulls, little difference was found between August 1995 and converted evaluations in measures of accuracy of prediction; mean differences were less for converted evaluations, but the mean is a much less useful statistic for determining predictive ability than are measures of variation. For bulls with a ≥50% increase in number of daughters, converted evaluations for German bulls tended to be slightly superior for predicting February 1996 INTERBULL evaluations, but the August 1995 INTERBULL evaluations clearly were better predictors for Netherlands bulls.

CONCLUSIONS

Mean evaluations on a US basis were essentially unchanged for US bulls between INTERBULL evaluations in August 1995 and February 1996; evalua-

TABLE 5. Intercepts (a) and regression coefficients (b) by birth year for conversion of protein yield evaluations to a US basis.

Birth	Canada		France		Germany		Italy		The Netherlands	
year	a	b	a	b	a	b	a	b	a	b
	(kg)		(kg)		(kg)		(kg)		(kg)	
1980	–7.3	0.389	–1.2	0.528	–16.4	0.628	–8.7	0.527	–4.0	0.561
1981	–6.6	0.391	–0.6	0.540	–14.9	0.641	–8.1	0.533	–3.9	0.570
1982	–6.2	0.394	–0.2	0.559	–15.8	0.640	–8.2	0.532	–3.6	0.590
1983	–5.9	0.385	–0.1	0.532	–15.6	0.664	–8.2	0.554	–3.3	0.603
1984	–5.7	0.382	–0.8	0.530	–14.7	0.653	–7.8	0.548	–3.3	0.592
1985	–5.5	0.390	–0.4	0.522	–14.0	0.644	–7.8	0.540	–2.6	0.618
1986	–5.3	0.387	0.4	0.530	–13.2	0.666	–7.7	0.567	–2.5	0.637
1987	–5.4	0.389	1.0	0.544	–11.5	0.672	–7.6	0.560	–1.1	0.657
1988	–3.6	0.392	1.5	0.531	–10.7	0.664	–7.0	0.559	–0.2	0.660
1989	–3.3	0.382	2.4	0.498	–10.7	0.648	–6.4	0.546	0.3	0.656
1990	–2.2	0.387	3.1	0.502	–9.3	0.624	–6.4	0.552	0.6	0.671

tions for bulls from other countries increased about 14 kg for milk and 0.4 kg for fat and protein (Table 1). Although changes are normal for individual bulls and the latest results are assumed to be superior because of additional data, a change for a group of thousands of bulls is not easy to interpret. Except for The Netherlands, evaluations for top bulls tended to decline, especially for the US and Germany (Table 1), and tended to reflect changes in national evaluations.

Mean genetic merit of US parents of bulls sampled in five countries tended to overestimate bull merit, but differences tended to be largest for US bulls (Table 2). Solutions for country of bull generally were not different ($P > 0.05$) for other countries relative to the US. On a US basis, solutions from a model that accounted for PA (Table 3) were higher ($P < 0.01$) for both German and Netherlands bulls than those for US bulls. However, these differences were <1 kg of PTA of protein. Of greater importance was the finding that French bulls that were full brothers to US bulls had higher ($P < 0.05$) milk and protein solutions on the basis of either country (Table 4). A bias of about 100 kg of EBV for milk yield and 3 kg for protein yield raises serious questions about comparability of INTERBULL evaluations.

Intercepts for conversion equations to a US basis increased by bull birth year (Table 5) and correspondingly decreased for conversions from a US basis. Both intercepts and regression coefficients increased by birth year for equations from The Netherlands to France but showed no trend in the other direction. The transformation of European Holstein populations to North American genetics explains part of this trend. Hybrid vigor inflated the apparent genetic merit of US bulls in early years, but the impact of heterosis has declined as US and European populations have become more similar in recent years. However, the effect of heterosis does not explain the trend observed for conversions from The Netherlands to France.

Previous INTERBULL evaluations were generally more accurate predictors of later INTERBULL evaluations than were conversions from more recent national evaluations. Although this finding was true for Netherlands bulls (even with ≥25% and ≥50% increases in numbers of daughters for converted evaluations), accuracy of prediction was similar for previous INTERBULL and converted national evaluations for

TABLE 6. Differences between February 1996 International Bull Evaluation Service (INTERBULL) evaluations on a US basis and predicted evaluations from August 1995 INTERBULL evaluations and conversions from interim national evaluations.

Exporting country	Trait	Difference from August 1995 INTERBULL evaluations			Difference from converted interim national evaluations		
		$\bar{X}$	SD	$\lvert\bar{X}\rvert$	$\bar{X}$	SD	$\lvert\bar{X}\rvert$
		(kg)					
All bulls							
Germany	Milk	18	52	36	–69	107	105
(7213 bulls)	Fat	0.4	2.0	1.2	–3.5	4.2	4.7
	Protein	0.4	1.7	1.1	–2.2	3.1	3.2
The Netherlands	Milk	10	28	19	–28	89	76
(3404 bulls)	Fat	0.2	1.2	0.7	–1.2	3.2	2.8
	Protein	0.3	0.9	0.6	–0.7	2.5	2.1
Bulls with ≥25% increase in number of daughters							
Germany	Milk	–39	158	125	–12	154	118
(345 bulls)	Fat	–1.8	6.0	4.8	0.7	5.4	4.3
	Protein	–1.7	5.0	4.0	–1.1	4.7	4.0
The Netherlands	Milk	41	78	68	–8	121	103
(139 bulls)	Fat	1.8	3.2	2.8	0.3	3.8	3.3
	Protein	0.9	2.4	2.0	–0.5	3.3	2.7
Bulls with ≥50% increase in number of daughters							
Germany	Milk	–60	179	151	–27	156	131
(198 bulls)	Fat	–2.4	6.7	5.7	–0.4	5.8	4.7
	Protein	–2.2	5.5	4.7	–1.4	5.1	4.5
The Netherlands	Milk	32	87	71	–22	131	114
(77 bulls)	Fat	1.4	3.6	2.9	–0.3	3.9	3.4
	Protein	0.6	2.5	1.9	–0.9	3.6	3.1

German bulls when daughters increased by ≥25%, and converted evaluations were somewhat more accurate predictors when daughters increased by ≥50%.

The appropriateness of using a converted new evaluation or the previous INTERBULL evaluation for a foreign bull depends on the amount of additional information in the new evaluation versus the amount of information from daughters in other countries in the INTERBULL evaluation. For example, a new Netherlands evaluation for Sunny Boy would include some extra daughters from The Netherlands but would exclude the many Sunny Boy daughters around the world. Because definition of a threshold for new information at which conversion should be used is not practical, the latest INTERBULL evaluations should continue to be used. As INTERBULL procedures continue to improve, conversions will become less useful because they can only use data from a single country. Because of extensive international trade in semen, the number of countries in which a bull has relatives will increase. Harmonization of release times for evaluations also will minimize the need for converted evaluations. Conversion should be used only for bulls that do not have INTERBULL evaluations.

Improvements in methodology that would increase consistency of evaluations across time and location may be possible. Alternatively, users may need to accept that a degree of uncertainty and error exists in international evaluations because of limitations of available data and methodology.

The bulk of evidence presented suggests that INTERBULL rankings of US bulls may not have been as high as warranted by their merit. During the review process of this paper, the INTERBULL procedure was modified to include only more recent data that had a significant impact on estimated genetic variances and resulting evaluations. Further research will be required to determine the degree of improvement.

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REFERENCES

1 Banos, G. 1995. Application of international sire evaluations. J. Dairy Sci. 78(Suppl. 1):221.(Abstr.)
2 Philipsson, J. 1994. Report for 1993/94 at the INTERBULL meeting in Ottawa, Ontario, Aug. 5–6, 1994. Proc. Open Session INTERBULL Annu. Mtg., Ottawa, Canada, August 5–6, 1994. Int. Bull Eval. Serv. Bull. No. 10. Dep. Anim. Breed. Genet., SLU, Uppsala, Sweden.
3 Powell, R. L., and G. R. Wiggans. 1995. Holstein conversion equations based on population variances and a full-brother model. J. Dairy Sci. 78:1362.
4 Schaeffer, L. R. 1985. Model for international evaluation of dairy sires. Livest. Prod. Sci. 12:105.
5 Schaeffer, L. R. 1994. Multiple-country comparison of dairy sires. J. Dairy Sci. 77:2671.
6 Sigurdsson, A., and G. Banos. 1995. Dependent variables in international sire evaluations. Acta Agric. Scand. 45:209.
7 Sigurdsson, A., and G. Banos. 1995. Estimation of genetic correlations between countries. Proc. Open Session INTERBULL Annu. Mtg., Prague, Czech Republic, September 7–8, 1995. Int. Bull Eval. Serv. Bull. No. 11. Dep. Anim. Breed. Genet., SLU, Uppsala, Sweden.
8 Wiggans, G. R., I. Misztal, and L. D. Van Vleck. 1988. Implementation of an animal model for genetic evaluation of dairy cattle in the United States. J. Dairy Sci. 71(Suppl. 2):54.