Accuracy of MACE Evaluation for Composite Type Traits Compared to Prediction Based on Linear Traits

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Introduction

For several years, Interbull evaluations for conformation traits have been available for Brown Swiss, Guernsey, Holstein and Jersey breeds. In November 2003, Interbull started computing international evaluations for Ayrshire Conformation Traits. CDN publishes MACE EBV for all linear traits, and predicted EBV for all major trait composites, with the exception of overall conformation. Composite traits are predicted using many linear traits with a multiple regression. Results for the Ayrshire breed have highlighted some problems with conformation: low genetic correlations across countries and some countries that did not provide overall Conformation to Interbull. Problems with low correlations were already present in other breeds for the same trait. Average genetic correlations between Canada and other countries for conformation are .493, .666, .715, .761 and .604 in Ayrshire, Brown Swiss, Guernsey, Holstein and Jersey, respectively (Table 1).

Recently, there has been much discussion among Interbull members on ways to express EBV for overall Conformation for foreign bulls. Interbull includes 16 linear traits and 3 composite traits in the MACE evaluation. Some countries rebuild the composite traits using prediction equations with the MACE linear traits, while other countries directly publish the MACE EBV on their own country scale.

The objectives of this investigation were to compare MACE evaluations for composite type traits with predictions based on linear traits and to examine the accuracy of each approach by estimation of reliability for the resulting MACE evaluations.

Materials and Methods

All official Ayrshire, Brown Swiss, Guernsey, Holstein and Jersey domestic bull proofs from May 2004 Type run were analyzed. Composite traits included overall Conformation, Mammary System and Feet & Legs.

A multiple regression analysis that maximized the adjusted R-square value was completed. Secondly, the level of significance of each factor included in the analysis was examined, in order to obtain the best prediction in terms of the highest level of adjusted R-square and removal of nuisance variables. Only linear traits that were included in each breed MACE evaluation were used in the multiple regression. Bulls born between 1989 and 1998 were included in the analysis for Holstein, and bulls born between 1984 and 1998 were included in the analysis for the other four breeds.

Reliability of the predicted composite traits was calculated as the MACE reliability (on the Canadian scale) of the linear traits used in the prediction equation weighted by the relative emphasis of each trait in the prediction equation. The reliability was then multiplied by the R-square obtained from the prediction of the multiple regression for that specific composite trait.

Finally, combining the MACE EBV and the predicted EBV, a blended EBV for each composite trait was calculated as follows:

$$EBV_{blended} = (w_1 EBV_{MACE} + w_2 EBV_{Pred}) / (w_1 + w_2)$$

where w_i = reliability$_i$ / (1-reliability$_i$), with i=1 for MACE reliability, and i=2 for predicted reliability. The reliability of the blended EBV was estimated as being equal to the highest value between the MACE and predicted reliability.

Results and Discussion

In Table 2, adjusted R-square for prediction equations are shown for the three composite traits in the five breeds. Generally, the values of R-square were higher for overall Conformation than for the other two composites. As expected, the R-square for predicted Feet & Legs was lowest in all breeds. This is due to the low number of linear Feet & Legs traits included in MACE evaluations. For example in Holsteins, Heel Depth and Bone Quality are important traits to build the Feet & Legs composite in Canada, but are excluded from Interbull evaluations. Furthermore, defective characteristics have strong effect on Feet & Legs. In a separate analysis, defective characteristics were included in the model and the R-Square was 15% higher than the prediction when they were excluded.

Table 3 shows descriptive statistics for the three types of EBV and reliabilities for all Holstein foreign bulls (MACE, predicted and blended). The overall mean was similar for the three type of EBV across the three composites. The predicted reliability was slightly higher than MACE reliability for Conformation, but much lower for Mammary System and Feet & Legs.

Average EBV reliabilities by country of bull origin are shown in Table 4 for Holstein and Table 5 for other breeds. Country of origin was assigned as the country where the bull had the highest number of daughters. In Holsteins, the predicted reliability was lower than the MACE reliability for 50, 64 and 69% of all countries for overall Conformation, Mammary System and Feet & Legs, respectively. Percentages were much higher for Brown Swiss (83, 67, 83%), and much lower for Ayrshire (25, 50, 37%) and Jersey (29, 43, 29%). This shows quite clearly that the advantage of predicting composite traits largely depends on the country of origin of the bulls and on the breed evaluated.

Differences in country of origin and breeds between MACE and predicted reliabilities are largely affected by genetic correlations within breed-country-trait combinations. In Table 6 genetic correlations between Canada and other countries of evaluation are presented for overall Conformation. In the same Table a predicted correlation is included. The predicted correlation was computed summing correlations of each linear trait included in the prediction equation for overall conformation, weighted by the relative emphasis of each linear trait in the prediction equation for overall conformation. The linear relationship between correlations and reliabilities was quite evident when differences between genetic and predicted correlations were plotted against differences between MACE and predicted reliabilities (Figure 1).

Previous discussions have been about which approach is better, using the MACE evaluation of the composite trait or using the Prediction approach based on MACE evaluations of the linear traits in the composite. The determining factor has typically been "which is more accurate?". In other words, either approach is acceptable, but which EBV includes the most information? Choosing one approach over the other usually means more accurate EBV for some countries and traits, but less accurate EBV for others. The new option proposed in this study is to therefore use the information from both approaches by blending the results. With blending, the maximum accuracy is achieved in all cases.

The EBV are combined in the blended approach using a weighted average instead of using selection index, to guarantee that no information is double counted. For example, the composite trait evaluation in some countries may have been derived from component trait evaluations rather than a separately recorded trait, or the correlation among EBV using either approach may be very close to one. There is no double counting with the weighted average approach because the weights always sum to 1, allowing for the potential of multiple predictors based on the same or very similar data. In contrast, a selection index approach would have involved weights that typically sum to a value greater than 1. Consistent with the weighted-average approach, the reliability after blending is set to its minimum possible value, which is the maximum of the contributing reliabilities. There are many examples in Tables 4 and 5 of higher reliabilities with the blended approach relative to using either the MACE or Prediction approaches on their own. Perhaps more importantly, there is much less variation in reliabilities by country of origin with the blended approach, so bulls from all countries can be more easily compared.

Conclusion

Predicted EBV and reliabilities were calculated for overall Conformation, Mammary System and Feet & Legs. Predicted reliabilities were heavily affected by level of genetic correlations across countries. For most bulls the MACE reliability was higher than the predicted reliability. A blended EBV weighted by the relative reliabilities of MACE and predicted EBV was outlined.

Table 1. Average genetic correlations between Canada and other countries (Interbull, Feb 2004).

	AYS	BSW	GUE	HOL	JER
Stature	.914	.860	.985	.942	.905
Chest width	.614	.760	.795	.854	.673
Body depth	.613	.710	.915	.811	.538
Angularity	.713	.596	.795	.776	.696
Rump angle	.933	.964	.965	.960	.955
Rump width	.757	.738	.930	.883	.723
Rear leg set	.769	.896	.600	.882	.652
Rear leg rear view				.833	
Foot angle	.619	.538	.470	.759	.710
Fore udder	.735	.598	.790	.843	.790
Rear udder height	.784	.844	.915	.844	.752
Udder support	.755	.834	.685	.810	.750
Udder depth	.888	.530	.915	.949	.918
Fore Teat placement	.853	.955	.895	.947	.912
Teat length				.772	
Rear Teat placement	.827	.875		.960	.850
Overall Conformation	.493	.666	.715	.761	.604
Mammary System	.725	.808	.490	.815	.803
Feet & Legs	.430	.513	.690	.742	.580

Table 2. Adjusted R-square for prediction equations.

	AYS	BSW	GUE	HOL	JER
Conformation	.869	.827	.870	.889	.915
Mammary System	.867	.810	.793	.887	.869
Feet & Legs	.522	.213	.618	.567	.615
Number of bulls	*398*	*77*	*59*	*4188*	*226*

Table 3. Descriptive statistics of EBV and reliabilities (Holstein) on the Canadian scale.

			N	Mean	SD	Min	Max
Overall Conformation	EBV	Blended	63157	-4.09	4.62	-27	16
		MACE	57383	-4.07	4.72	-26	16
		Predicted	63157	-3.97	4.70	-31	17
	Reliability	Blended	63157	56.70	10.20	11	94
		MACE	63157	51.80	19.09	0	94
		Predicted	63157	52.02	10.79	11	84
Mammary System	EBV	Blended	63157	-3.28	4.69	-26	16
		MACE	61730	-3.28	4.70	-26	16
		Predicted	63157	-3.14	4.90	-28	17
	Reliability	Blended	63157	61.10	9.61	9	94
		MACE	63157	59.91	13.23	0	94
		Predicted	63157	51.94	9.62	5	84
Feet & Legs	EBV	Blended	63157	-1.46	3.54	-18	13
		MACE	48757	-1.15	4.05	-20	14
		Predicted	63157	-1.47	3.42	-19	16
	Reliability	Blended	63157	41.76	17.18	1	92
		MACE	63157	38.13	22.55	0	92
		Predicted	63157	26.37	10.24	1	53

Table 4. Average EBV reliability (B=blended, M=MACE, P=predicted) by country of bull origin (Holstein).

		Conformation			Mamm. System			Feet & Legs		
Origin	N	B	M	P	B	M	P	B	M	P
AUS	1649	46.6	46.4	43.5	48.7	48.5	46.4	27.5	26.5	16.4
BEL	49	56.8	56.8	31.1	47.1	47.0	27.9	19.5	17.1	9.0
CHE	369	73.8	73.8	61.7	74.3	74.3	63.9	54.9	54.9	27.2
CHR	474	53.0	48.7	35.5	46.6	41.0	42.5	35.8	34.6	9.3
CZE	350	53.1	5.8	53.0	52.2	5.9	52.1	24.5	4.4	23.0
DEU	10245	58.8	58.7	54.6	57.6	57.5	53.6	48.1	42.4	28.7
DNK	4654	54.2	45.5	54.2	61.0	61.0	49.7	53.8	53.8	32.6
DNR	141	49.0	23.5	49.0	42.7	35.7	42.6	51.8	51.8	28.7
ESP	450	67.7	66.5	67.5	72.3	72.3	61.8	69.1	69.1	41.2
FIN	387	40.1	.0	40.1	44.2	.0	44.2	16.6	.0	16.6
FRA	7047	48.5	28.3	46.0	63.3	63.3	51.9	25.4	19.0	19.0
GBR	1707	54.3	53.2	53.7	55.0	52.3	52.7	46.0	45.0	26.1
HUN	598	60.6	60.6	51.4	55.8	55.8	48.0	35.8	26.0	27.5
IRL	516	50.8	22.7	50.5	50.3	22.9	48.8	30.4	19.6	22.7
ITA	3949	59.7	59.6	57.5	68.9	68.9	54.2	43.5	37.1	31.0
JPN	2010	56.3	56.3	47.8	53.0	53.0	45.5	45.9	44.0	24.2
NLD	6001	59.8	58.1	50.7	64.0	64.0	51.4	49.0	49.0	23.0
NZL	2196	51.8	51.8	34.6	63.6	63.6	47.2	5.3	3.0	4.3
POL	2557	39.6	29.3	39.6	37.5	35.0	37.4	27.3	27.3	17.4
SWE	539	54.5	45.5	54.5	58.1	58.1	49.2	47.9	47.9	33.1
USA	15479	63.4	63.2	57.9	67.3	67.3	56.2	47.5	44.1	33.1
ZAF	242	40.8	.0	40.8	43.8	.0	43.8	16.4	.0	16.4

Table 5. Average EBV reliability (B=blended, M=MACE, P=predicted) by country of bull origin (other breeds).

		Conformation			Mamm. System			Feet & Legs		
Origin	N	B	M	P	B	M	P	B	M	P
		Ayrshire								
AUS	128	30.9	28.3	30.4	39.5	39.5	35.9	11.0	3.3	10.6
DNK	952	45.2	14.4	45.2	59.0	59.0	44.0	39.0	39.0	24.0
FIN	1227	29.3	.3	29.3	32.2	.5	32.2	16.4	.2	16.3
GBR	127	46.3	19.2	46.3	41.1	20.2	41.0	28.1	14.5	27.5
NOR	1988	22.6	7.3	22.5	31.1	28.6	30.6	36.4	36.4	12.1
NZL	282	25.4	17.3	25.0	59.6	59.6	36.3	2.8	.0	2.8
SWE	625	44.0	43.3	42.7	62.8	62.8	45.8	46.5	46.5	21.8
USA	57	54.6	54.6	47.6	48.7	.7	48.7	24.9	.5	24.9
Mean		31.8	12.9	31.5	42.1	32.9	35.9	30.8	26.2	16.3
		Brown Swiss								
CHE	926	62.7	60.3	45.2	79.2	76.8	45.7	56.3	55.8	8.3
DEA	1025	38.0	1.6	37.6	61.6	60.4	38.7	48.8	48.6	4.0
FRA	64	81.6	80.9	51.7	72.8	72.8	49.5	36.2	36.2	13.5
ITA	699	65.9	65.9	43.5	68.4	68.4	37.8	14.1	2.9	11.9
NLD	17	66.5	66.5	40.9	47.9	44.9	40.4	24.8	24.8	6.8
USA	361	65.1	64.2	49.7	54.7	30.3	45.5	29.4	22.3	11.4
Mean		55.9	43.0	42.9	67.8	63.8	41.6	40.5	37.0	8.1
		Guernsey								
GBR	50	48.7	41.0	43.2	41.0	19.3	41.0	19.8	15.7	15.1
USA	448	46.3	46.2	44.0	39.0	1.5	39.0	27.0	1.2	27.0
Mean		46.5	45.7	44.0	39.2	3.2	39.2	26.3	2.6	25.8
		Jersey								
AUS	281	36.8	32.4	36.7	42.5	42.2	38.6	17.6	15.3	15.2
DNK	1117	46.2	32.7	46.2	66.5	66.5	43.0	31.0	26.3	30.3
GBR	50	61.8	58.8	40.6	55.8	50.3	43.8	45.5	43.6	17.0
ITA	3	40.3	38.0	40.3	35.0	.0	35.0	25.7	22.0	25.0
NZL	1488	32.7	32.6	27.8	52.7	52.7	27.5	6.4	.2	6.4
USA	1536	54.0	37.1	54.0	54.3	2.3	54.3	28.9	.7	28.9
ZAF	142	40.4	.0	40.4	42.0	.0	42.0	23.9	.0	23.9
Mean		43.9	33.4	42.0	55.7	37.0	41.5	21.5	8.1	20.8

Table 6. Genetic and predicted correlations between Canada and other countries for overall Conformation (Holstein).

Country of origin	Predicted Correlation	Genetic Correlation
AUS	.73	.54
BEL	.19	.43
CHE	.89	.93
CHR	.66	.93
CZE	.80	
DEU	.89	.83
DNK	.90	.64
DNR	.84	.29
ESP	.90	.83
FIN	.79	
FRA	.87	.85
GBR	.89	.77
HUN	.83	.86
ITA	.86	.86
JPN	.87	.90
NLD	.88	.79
NZL	.50	.72
POL	.75	.47
SWE	.82	.68
USA	.89	.87
ZAF	.78	

Figure 1. Differences between genetic and predicted correlations by differences between MACE and predicted reliabilities (Holstein).