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CORRELATIONS AND GENETIC TRENDS FOR SELECTION INDICES ASSESSED USING AUSTRALIAN AND NORTH AMERICAN BULL PROOFS

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SUMMARY

The aim of this research was to evaluate correlations between national selection indices and estimate the rates of genetic gain within and between countries, using bull breeding values from Australia, USA and Canada. High ranking sires in the USA and Canada do not necessarily rank highly in Australia. The correlations between bull proofs in Australia and either Canada or USA ranged between 0.74 and 0.86 for the indices assessed, implying that national breeding objectives and genotype by environment interactions are important. Since 2010, which is similar to the start of widespread use of genomic bulls, there has been considerable increase in the rate of genetic gain in all three countries.

INTRODUCTION

The concept that animals do not always rank the same in different environments, or that there is an advantage to a genotype in one environment that is not seen in another environment is known as a genotype by environment (GxE) interaction (Falconer and Mackay, 1996). Typically, animal breeders are more concerned about the re-ranking of animals than the differences in scale between environments. If re-ranking is substantial, then specific genotypes are required for specific environments, a correlation of >0.8 is often considered to be a threshold of importance, although it is somewhat arbitrary (Falconer and Mackay, 1996).

International exchange of genotypes is very common in dairy cattle breeding and therefore a bull can sire cows in more than one country at the same time. For these bulls and their relatives, it is possible to calculate correlations of their proofs between countries, which is indicative of GxE. Interbull, the international bull evaluation service already provides some of this information for traits such as milk production and somatic cell count, however for national selection indices there are no comparisons. In Australia, in addition to the Balanced Performance Index (BPI), there are two other national selection indices available from DataGene (the Health Weighted Index and Type Weighted Index) that align with farmer philosophies (Martin-Collado *et al.*, 2015). Similarly, in the USA there are five indices for farmers to choose between. The combination of traits within an index and their respective weights varies by country, which will reduce correlations between indices.

Within country, the success of a breeding programme is often assessed as the rate of genetic gain achieved, especially in the primary selection tool, such as a selection index. Genomic selection was predicted to double the rate of genetic gain mainly through the shortening of the generation interval (Shaeffer, 2006). Since 2010, genomic selection programs have been widely adopted in genetic evaluations around the world (Pryce and Daetwyler, 2011). To date, there have been relatively few studies that have compared the realised rate of genetic gain before and after the implementation of genomic selection.

The aim of this study was to evaluate correlations between Australian, USA and Canadian indices and rates of genetic gain in these indices. For comparison, a selected number of traits (stature, milk yield and overall type) genetic correlations between countries were also estimated.

MATERIALS AND METHODS

Selection indices and breeding values of predicted transmitting abilities (PTAs) from Holsteins in Australia, USA and Canada were used in the analyses. The bull breeding value file from DataGene was used for the Australian analysis (accessed April 2015; n=9,470). The data, included both Australian Breeding Values (ABV) for bulls (n=7,423) and bulls that had an international proof determined by Interbull (ABV(i)) (n=2,047). The American data was provided by the Council on Dairy Cattle Breeding (CDCB) (n=287,207). Total Performance Index (TPI) is another USA index, that was accessed directly from Holstein USA (Tom Lawlor personal communication, 2015) (n=4,080). The Canadian bull proof file (April 2015) was downloaded from the Canadian Dairy Network (CDN) in June 2015 (n=12,269).

The bull files were merged based on their international IDs, where only bulls born after 1990 were considered. The number of bulls that had dual proofs with Australia was 8,226 with USA indices (NM, CM, FM and GM), 2,981 with TPI data and 1,874 with the Canadian index.

Table 1: List of indices used in the evaluation and their country of origin

Abbreviated index	Index name	Country	Source	No. of Bulls
BPI	Balanced performance index	Australia	DataGene	9,470
HWI	Health weighted index	Australia	DataGene	9,470
TWI	Type weighted index	Australia	DataGene	9,470
TPI	Total performance index	USA	Holstein USA	4,072
NM	Net merit	USA	CDCB	151,246
CM	Cheese merit	USA	CDCB	151,246
FM	Fluid merit	USA	CDCB	151,246
GM	Grazing merit	USA	CDCB	151,246
LPI	Lifetime profit index	Canada	CDN	9,217

Pearson correlations between indices were calculated using merged data using the statistical package R (R Core Team, 2013).

The genetic trends were calculated as regressions of breeding values (or PTAs) on year of birth for bulls born between 1990-2000; 2000-2010 and from 2010. To make comparisons between countries, the genetic trends were transformed into genetic standard deviations using the genetic standard deviation associated with each time period. The standard deviation for each interval (e.g. between 1990-2000) was calculated by taking the mean standard deviations per year over the period, then calculating the mean of the SD values within each time interval. The regression was divided by this number to give the rate of genetic gain in standard deviation units.

RESULTS AND DISCUSSION

Correlations within countries were high and reasonably strong correlations exist between Australian indices and all the American indices (Table 2). Removing bulls that only have an Interbull proof had minimal effects on the correlations (below the diagonal). Correlations of the Canadian LPI with the Australian indices ranged between 0.83 and 0.86 (Table 3). BPI seems to be more closely related to LPI than NM or TPI (0.86, 0.81 and 0.77 respectively).

The correlations presented in Tables 2 and 3 indicate the relative response to selection that could be expected when selecting based on a foreign index. Ranking bulls using any of the Australian indices will result in similar sires being selected, as the correlations between BPI, HWI and TWI are very high (0.98, 0.95 and 0.94). When selecting bulls in Australia using their North American index, sire re-ranking is expected, as the correlations between the Australian index and North American indices range from 0.77 for BPI and TPI, 0.81 for BPI and NM to 0.86 for BPI and LPI. However, the correlations between indices depend on three factors; firstly, the traits in the indices and their respective weights. It is very likely that genuine economic drivers differ between countries. Secondly, whether true genotype by environment interactions are occurring and thirdly, the differences in trait definition between countries. Sires that rank highly for their respective indices in the USA or Canada do not necessarily rank highly in Australia.

Table 2: Correlations of Australian indices (Balanced Performance Index (BPI), Health Weighted Index (HWI) and Type Weighted Index (TWI)) with USA indices (Net Merit (NM), Cheese Merit (CM), Fluid Merit (FM), Grazing Merit (GM) and Total Performance Index (TPI)), above the diagonal includes both domestic and interbull proofs, below the diagonal is domestic proof only.

	BPI	HWI	TWI	NM	CM	FM	GM	TPI
BPI		0.98	0.95	0.81	0.83	0.75	0.81	0.77
HWI	0.98		0.94	0.82	0.83	0.77	0.82	0.78
TWI	0.96	0.95		0.81	0.82	0.77	0.79	0.81
NM	0.80	0.80	0.78		1.00	0.99	0.99	0.97
CM	0.81	0.81	0.79	1.00		0.97	0.99	0.97
FM	0.74	0.76	0.74	0.99	0.98		0.97	0.97
GM	0.79	0.80	0.76	0.99	0.99	0.98		0.96
TPI	0.76	0.76	0.78	0.98	0.97	0.97	0.97	

SEs<0.02

Table 3: Correlations of Australian indices (Balanced Performance Index (BPI), Health Weighted Index (HWI) and Type Weighted Index (TWI)) with the Canadian index Lifetime Profit Index (LPI; CAN) above the diagonal includes both domestic and interbull proofs, below the diagonal is domestic proof only.

	BPI	HWI	TWI	LPI
BPI		0.98±0.01	0.95±0.01	0.86±0.02
HWI	0.97±0.01		0.94±0.01	0.83±0.02
TWI	0.94±0.01	0.93±0.01		0.86±0.02
LPI	0.83±0.02	0.80±0.03	0.83±0.02	

It should be noted, that when correlations between traits instead of indices were estimated, those that were objectively scored had strong correlations (stature 0.94 AUS-CAN), suggesting little to no GxE. Similarly, there was a moderate correlation with milk yield across all three countries (0.83 AUS-USA and 0.88 AUS-CAN). Composite traits, that are more subjectively measured, typically had lower correlations with AUS, such as overall conformation, for example for overall type the correlations were 0.56 AUS-CAN and 0.59 AUS-USA although there are differences in trait definition between countries and increased error variance (subjectivity) in some traits may also be driving weak correlations, there is likely to be GxE as well.

For all indices, the rate of genetic gain has increased dramatically since 2010 (Table 4). Rates of genetic gain were higher when all bulls were included and analysed based on their country of origin compared to bulls with dual proofs (Table 4 vs. Tables 5 and Table 6) and reflects the overall increase in genetic gain in these countries. The rate of genetic gain for bulls with proofs in Australia and a North American country was faster for TPI and LPI (Tables 5 and 6), implying that sires in Australia are being selected based on their international proof. There has been an increase in the number of international bulls used in recent years, with around 45% of daughters of registered bulls being sired by North American bulls since 2010, which compares to 28% from 2000-2010. The reduced rate of genetic gain seen in the Australian indices with dual proofs compared to North American indices could be explained by the GxE interaction that exists and bulls that rank highly on the USA or Canadian indices are not necessarily well suited to the Australian environment reflecting the lower rate of genetic gain. These rate of genetic gain since

2010 should be treated cautiously, as the number of years of data in the analysis was comparatively small. Rates of genetic gain should be re-estimated as more data becomes available.

Table 4: Holstein genetic trends in genetic standard deviations calculated as the regression of indices on year of birth for the following time intervals; 1990-2000, 2000-2010, 2010-now; for all available bulls with progeny in the country of origin (Australia – BPI, HWI, TWI (n=7,412); USA – TPI (n=4,072), NM (n=151,246); Canada - LPI (n=5,663))

	BPI	HWI	TWI	TPI	NM	LPI
SD of index*	66.4	56.2	66.3	220	98.2	261
1990-2000	0.20±0.002	0.17±0.002	0.20±0.002	0.29±0.004	0.25±0.000	0.22±0.003
2000-2010	0.22±0.005	0.22±0.005	0.24±0.005	0.30±0.007	0.32±0.001	0.32±0.007
2010-now	0.42±0.037	0.44±0.038	0.48±0.036	0.68±0.039	0.40±0.003	N/A

*The overall standard deviation

Table 5: Holstein genetic trends calculated in genetic standard deviations as the regressions of indices on the following time intervals; 1990-2000, 2000-2010; for bulls with dual proofs in Australia and USA for all indices except TPI, the number of bulls used was 8,548. For TPI 2,981 bulls were used that had dual proofs

	BPI	HWI	TWI	TPI	NM	CM	FM	GM
1990-2000	0.15	0.14	0.16	0.25	0.16	0.15	0.15	0.15
2000-2010	0.15	0.16	0.17	0.30	0.25	0.07	0.23	0.24

SEs<0.01

Table 6: Holstein genetic trends in genetic standard deviations calculated as regressions of the following time intervals; 1990-2000, 2000-2010; for bulls with dual proof in Australia and Canada (n=1,874)

	BPI	HWI	TWI	LPI
1990-2000	0.14	0.13	0.14	0.19
2000-2010	0.14	0.13	0.12	0.21

SEs<0.01

CONCLUSIONS

Sires that rank highly for their respective indices in the USA or Canada do not necessarily rank highly in Australia, with correlations between BPI and NM (USA), TPI (USA) and LPI (Canada) being 0.81, 0.77 and 0.86 respectively. Weak correlations are driven by GxE, different trait weightings and definitions and the degree of subjectivity of measuring traits in the indices. Since 2010, there has been a considerable increase in the rate of genetic gain in all countries. This could be a result of the introduction of genomics, the increase in the number of bulls being genomically tested and shorter generation intervals.

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