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Study on Genetic Evaluation for Linear Type Traits in Holstein Cows

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ABSTRACT : The objectives of this study were to i) investigate genetic performance for linear type traits of individual Holstein dairy cows, especially focusing on comparative traits, and to estimate genetic variances for these traits using actual data, and ii) compare genetic performance and improvement of progeny by birth country of the cows. Linear type traits defined with five comparative traits on this study were general stature composite (GSC), dairy capacity composite (DCC), body size composite (BSC), foot and leg composite (FLC), and udder composite (UDC). These traits were scored from 1 to 6 with 1 = poor, 2 = fair, 3 = good, 4 = good plus, 5 = very good and 6 = excellent. Final scores (FS) were also included in this study. Data used was collected from the years 2000 to 2004 by the Korea Animal Improvement Association (KAIA). Only data of more than five tested cows by herd appraisal date and by sires having more than ten daughters were included to increase the reliability of the data analyses. A total of 30,204 records of the selected traits, which was collected from 26,701 individuals having pedigree information were used. Herd appraisal date, year of age, lactation stage (grouped by month), and time lagged for milking (in hours) were assumed as fixed effects on the model. Animal additive genetic effects considering pedigree relationship and residual errors were assumed with random effects. Year of age at appraisal date was classified from one to nine years of age, assigning the value of nine years of age for animals that were greater than or equal to nine years of age. From our results, the estimate for heritability was 0.463, 0.346, 0.473, 0.290, and 0.430 on GSC, DCC, BSC, FLC and UDC, respectively. The estimate for FS heritability was 0.539. The greatest breeding values for GSC were estimated for Canada, with the breeding values for American lines increasing for 10 years starting in 1989 but tending to decrease after that until 2004. For DCC, the breeding values for American and Canadian lines showed similar patterns until 1999, after which the breeding values for the American lines declined sharply. For BSC, data from Korea, Canada and the USA followed similar trends overall except when the breeding values of the American lines decreased starting in 1999. Overall, the methods used to evaluate genetic performance in this study were acceptable and allowed for the discovery of differences by country of genetic origin, likely due in part to the American use of selection indexes based primarily on milk yield traits until methods for evaluating other traits began to emerge. (**Key Words :** Dairy Cattle, Linear Type Trait, Genetic Evaluation, International Comparison)

INTRODUCTION

During the past ten years, the number of dairy cows in South Korea declined by 90,000 from 550,000 to 460,000 while the number of dairy operations declined 33%, from about 24,000 to roughly 8,000. However, because milk yields per head have increased 25% (from 6,000 kg to 7,500 kg), the total lifetime milk yield was not affected, and this indicates increased performance and thus increased physiological stress on the cows. This physiological stress can have negative effects on other aspects of milk production. For example, the reproductive period increased 40 days from 400 to 440 days during the 10-year period reported previously, and, in 2005, of the 158,000 cattle tested, the animals usually considering the most productive (parity 3 to 5) comprised only 34% of the total cow herd with an average parity of 2.4 (Korean Agricultural Cooperative Federation, 2006), perhaps indicating decreased longevity of the animals. In addition, even though total milk yield is increasing, management costs are also increasing greatly, decreasing the efficiency and profitability of the industry. To solve these kinds of problems in other countries, the dairy industry has been making efforts for better economic proficiency of the population by selecting individuals with genetically excellent reproductive performance and body type, better udder development and increased production longevity.

Linear type traits can be used to maintain a more profitable herd of Holsteins through the selection of better

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Table 1. Information of data structure for linear type traits and type scoring traits in Holstein cows in South Korea

	N	Mean	SD	Min.	Max.
No. records/sire	325	92.9	173.8	11	1,212
No. records/HYS[1]	2,224	13.6	9.2	1	163
Age (yrs)	30,204	2.91	1.21	1	9
Lactation stage	30,204	5.59	3.09	1	12
Time after milking (h)	30,204	6.07	2.52	1	12

[1] Herd-Year-Season.

bulls. Understanding the trend of linear type traits can assist with the selection of a better group of mating sires. The Holstein Association USA has been testing linear type traits of cows, including fifteen basic linear type traits and total scores such as general stature composite (GSC), dairy capacity composite (DCC), body size composite (BSC), foot and leg composite (FLC), and udder composite (UDC) as a relatively comparative test among individuals. In South Korea, the Korea Animal Improvement Association (KAIA) has been responsible for testing using the USA body scoring system since 1980. Collected data has been used for selection of seedstock. Definitions and collection methods of scoring linear type traits have been reported by Song et al. (2002). The actual number of dairy cows tested by KAIA was about 32,000 in 2005, which is equivalent to 11.9% of total dairy cows. Dairy farmers in South Korea have been trying to select high-performing cows over multiple parities through comparative tests within contemporary groups; however, few studies involving genetic analyses of these traits have been conducted, likely due to the difficulties in estimating genetic parameters for animals with data collected with the comparative scoring method. The method used ranks the traits with one of six scores: poor, fair, good, good plus, very good, and excellent.

The development of alternative estimates of genetic performance would provide another selection tool for Korean milk producers and would also allow for comparison of animals by genetic country of origin. Therefore, the objectives of this study were to i) determine alternative methods to evaluate genetic performance for linear type traits of individual Holstein dairy cows, especially focusing on comparative traits, and to estimate genetic variances for these traits using actual data, and ii) compare genetic performance and improvement of progeny by birth country of the cows.

MATERIAL AND METHODS

Data

Data used in this study was collected from 118,290 Holstein dairy cows between the years of 2000 and 2004 by KAIA. Based on KAIA testing program rules, comparative traits were investigated on milking cows within herd without taking into account age and stage of lactation. Only data with more than five tested cows by herd appraisal date and of sires having more than ten daughters were included to increase the reliability of the data analyses. Outliers were removed and the records of individuals having data from one or both parents were included in the analyses. The data used in the analysis is a total of 30,204 records of the selected traits, which was collected from 26,701 individuals having pedigree information (Table 1).

Five comparative traits were investigated in this study, general stature composite (GSC), dairy capacity composite (DCC), body size composite (BSC), foot and leg composite (FLC), and udder composite (UDC). These traits were scored from 1 to 6 (Figure 1) by trained technicians with 1 = poor, 2 = fair, 3 = good, 4 = good plus, 5 = very good and 6 = excellent. Final scores (FS) also were determined with a range of 50 to 100 considered the linear type traits.

Statistical model

An analytical model was set based on a previous study designed to focus on estimating genetic parameters for these traits by threshold models using Gibbs sampling algorithms (Lee, 2006). Herd appraisal date, year of age, lactation stage (grouped by month), and time lagged for milking (in hours) were assumed as fixed effects in the model. Animal additive genetic effects considering pedigree relationship and residual errors were assumed with random effects. Year of

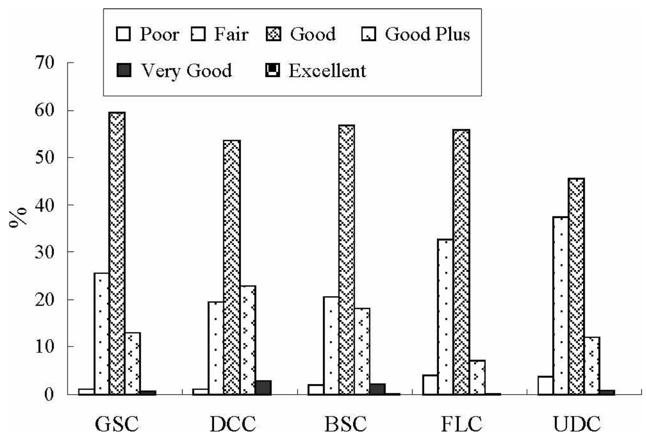

Figure 1. Type scoring traits in Holstein cows in South Korea. Traits analyzed included general stature composite (GSC), dairy capacity composite (DCC), body size composite (BSC), foot and leg composite (FLC) and udder composite (UDC).

Table 2. Estimates of heritabilities, genetic correlations and environmental correlations (their standard errors) for the type composite traits in dairy cattle in South Korea[1, 2]

	GSC	DCC	BSC	FLC	UDC	FS
GSC	0.463	0.636	0.739	0.614	0.491	0.828
	(0.020)	(0.035)	(0.029)	(0.042)	(0.033)	(0.016)
DCC	0.254	0.346	0.514	0.277	0.579	0.745
	(0.019)	(0.023)	(0.040)	(0.063)	(0.038)	(0.025)
BSC	0.313	0.169	0.473	0.362	0.368	0.687
	(0.020)	(0.020)	(0.019)	(0.046)	(0.038)	(0.023)
FLC	0.185	0.054	0.098	0.290	0.420	0.647
	(0.020)	(0.021)	(0.021)	(0.023)	(0.048)	(0.034)
UDC	0.231	0.234	0.147	0.168	0.430	0.868
	(0.020)	(0.018)	(0.022)	(0.020)	(0.021)	(0.010)
FS	0.561	0.495	0.425	0.385	0.783	0.539
	(0.015)	(0.015)	(0.018)	(0.018)	(0.008)	(0.017)

[1] Data on the diagonal represents heritabilities; data above the diagonal represents genetic correlations; data below the diagonal represents environmental correlations.

[2] GSC = General stature composite; DCC = Dairy capacity composite; BSC = Body size composite; FLC = Foot and leg composite; UDC = Udder composite.

age at appraisal date was classified from one to nine years of age, with the value of nine years of age assigned for animals that were greater than or equal to nine years of age. Lactation stage was classified by month from one to 12 months after parturition. Times of appraisal were classified into one of 12 h, using hourly intervals between milking and appraisal time. Statistical model was as follows:

$$y_{ijklmn} = \mu+HYS_i+AGE_j+STAGE_k+TIME_l+a_m+e_{ijklmn}$$

Where μ is overall mean, HYS_i is i^{th} Head-year-season at Appraisal date (i = 1 to 2224), AGE_j is j^{th} age effects (k = 1 to 9), $STAGE_k$ is k^{th} lactation stage (p = 1 to 12), $TIME_l$ is l^{th} Appraisal time effect (q = 1 to 12), a_m is m^{th} animal additive genetic effect and e_{ijklmn} is residual effects. In the equation, y_{ijklmn} is observed or non-observed latent variables.

Due to non-observed latent variables for type classification traits, genetic evaluation for these traits as well as final scores with assuming linear trait was adopted on a linear-threshold model using Empirical Bayes theorem providing by Quaas (2001) with multiple trait animal models. In this study, genetic parameters in Table 2 were used to estimate breeding values for these traits. This model was a linear-threshold model by likelihood approach, and was a conversion from BLUP90IOD (Misztal, 2008) using formulas given by Quaas (2000).

RESULTS AND DISCUSSION

Genetic parameters estimated in this study are provided in Table 2. Tsuruta et al. (2004) reported heritabilities of 0.40 to 0.49 in BSC, and 0.26 to 0.38 in UDC for analyzed linear type data from the Holstein Association USA with multiple-trait animal models using random regression. The heritability value for the present study for BSC (0.473) falls within the range reported by Tsuruta et al. (2004) but the UDC heritability value for the present study (0.430) is slightly higher than the value reported by Tsuruta et al. (2004). The genetic correlation between BSC and UDC reported by Tsuruta et al. (2004) was weak, estimated at -0.15 to 0.04, in contrast to the correlation of 0.368 noted in the present study for BSC and UDC. The heritability of BSC has been reported as 0.19 for first lactation cows and 0.22 for all cows, which was analyzed with ASREML using

Table 3. Threshold estimates for data collected from Holstein cattle in South Korea for general stature composite (GSC), dairy capacity composite (DCC), body size composite (BSC), foot and leg composite (FLC) and udder composite (UDC)

	Estimates			MC-SD for estimates		
	3	4	5	3	4	5
GSC	2.1477	3.1385	3.7926	0.0103	0.0222	0.0505
DCC	2.1929	3.2699	4.3436	0.0407	0.0747	0.1150
BSC	2.3512	3.4343	4.3732	0.0684	0.1052	0.1532
FLC	2.4868	3.6517	4.6930	0.0628	0.1003	0.2387
UDC	1.9793	2.8570	3.8591	0.0030	0.0083	0.0566

Table 4. Breeding value means±standard errors for data from Holsteins in South Korea with different genetic backgrounds for the following traits: general stature composite (GSC), dairy capacity composite (DCC), body size composite (BSC), foot and leg composite (FLC) and udder composite (UDC)

Country	No.	GSC	DCC	BSC	FLC	UDC	FS
Korea	18,784	0.33 ± 0.17^{b}	2.11 ± 0.15^{b}	-1.42 ± 0.18^{a}	-0.82 ± 0.16^{c}	0.71 ± 0.20^{ab}	0.56 ± 0.83^{b}
USA	13,705	0.65 ± 0.19^{b}	1.41 ± 0.18^{b}	-1.16 ± 0.21^{a}	1.90 ± 0.18^{b}	-1.15 ± 0.23^{b}	0.26 ± 0.97^{b}
Canada	4,762	2.35 ± 0.33^{a}	3.78 ± 0.30^{a}	-0.15 ± 0.36^{a}	0.59 ± 0.31^{bc}	2.21 ± 0.40^{a}	12.05 ± 1.65^{a}
Australia	436	-4.43 ± 1.09^{c}	-4.55 ± 1.00^{c}	0.43 ± 1.20^{a}	-3.80 ± 1.04^{d}	-4.70 ± 1.31^{c}	-23.94 ± 5.46^{c}
Japan	1,486	-0.98 ± 0.59^{b}	-3.16 ± 0.54^{c}	0.28 ± 0.65^{a}	4.60 ± 0.56^{a}	-1.05 ± 0.71^{b}	-3.47 ± 2.96^{b}

Values with different superscripts on same column differ significantly.

sire models with the data from the Holstein Association USA (Dechow et al., 2003) while the heritability for BSC in the present study was 0.473. However, in these analyses, the effect of age at calving nested within lactation, 5^{th} order polynomials of DIM, fixed herd-classification visit effects and random sire and error, etc. were included.

Genetic resources of Holstein in South Korea have been imported for several decades. Imported countries of genetic resources were identified in this study, and the breeding values by imported countries were compared, potentially providing a valuable reference for farmers who might be considering the importation of semen from abroad. The breeding values with standard errors as estimated by country of importation are represented in Table 4. The US had the largest set of data, followed by Canada, Japan and Australia. Among all countries, cows imported from Canada had greater breeding values for GSC, DCC, UDC, and FS, those from Australia had greater breeding values for BSC, and those from Japan had greater breeding values for FLC. The greater UDC breeding values from genetic sources imported from Canada is similar to that reported by Park et al. (2006).

Powell et al. (2003) reported EBV of conformation traits in several countries, with mean sire EBV for stature estimated at 0.87, -0.03 and -0.17 for Canada, Australia, and the USA, respectively. The authors also estimated mean sire EBV of fore udder and udder support as -0.45 and 0.09 in Australia, -0.06 and 0.40 in Canada, and -0.09 and -0.12 in the USA, respectively.

In the present study, the greatest breeding values for GSC were estimated for Canada with the breeding values for American lines increasing for 10 years starting in 1989 but tending to the decrease after that until 2004 (Figure 2A). For DCC, the breeding values for American and Canadian lines showed similar patterns until 1999, after which the breeding values for the American lines declined sharply (Figure 2B). For BSC, data from Korea, Canada and the USA followed similar trends, until the breeding values of the Amercian lines started decreasing in 1999 (Figure 2C). In the US, selection indexes were based primarily on milk yield traits until methods for evaluating other traits began to emerge, likely explaining this phenomenon. In 1994, selection indexes for somatic cell score and productive life were added, and in 2000, a composite type index for body size selection was added (Shook, 2006). The selection of a smaller, more feed efficient animal that would also maintain high a productive life would be beneficial to the dairy industry. Therefore, it is possible that American producers began to use productive life and body size indices for genetic selection, resulting in a doubling of downward selection pressure on animal size (Shook, 2006). Thus, the decrease noted in the present study for GSC, DCC and BSC breeding values (which could all be related in part to animal size) for American lines of Holsteins in South Korea from 1999 to 2004 would be expected.

Breeding values of FLC were estimated to be highest for lines from Canada in 1989, however, there was a similar pattern for Canada, Korea, and the USA after 1989 and up to 1999, with American lines having greater breeding values after 1999 compared to Canada and Korea (Figure 2D). The higher breeding values for the USA lines after 1999 are probably linked to the introduction of the foot and leg composite selection index to allow for greater selection of this trait in breeding animals starting in 2000 (Shook, 2006). However, an udder composite index for genetic selection was also added in 2000 for USA breeders (Shook, 2006), and since udder trait selection is important in dairy cattle, it is surprising that the breeding value decreased from 1999 to 2004 for the American lines for UDC. However, genetic selection is driven by the bulls provided for producers to choose from as well as their choices of traits for which they will base their selections, including production indexes. If selection of Holstein sires from America by South Korean producers emphasized traits negatively related to UDC in the years up to 1999, that might partially explain the decrease in UDC from 1999 to 2004 in the present study.

From 1984 to 1994, UDC breeding values of the three countries analyzed followed a similar pattern, however, those of Canada increased rapidly after 1994 and though South Korea and USA values were similar until 1999, breeding values for American lines decreased after 1999, as previously noted (Figure 2E). Breeding values of FS were

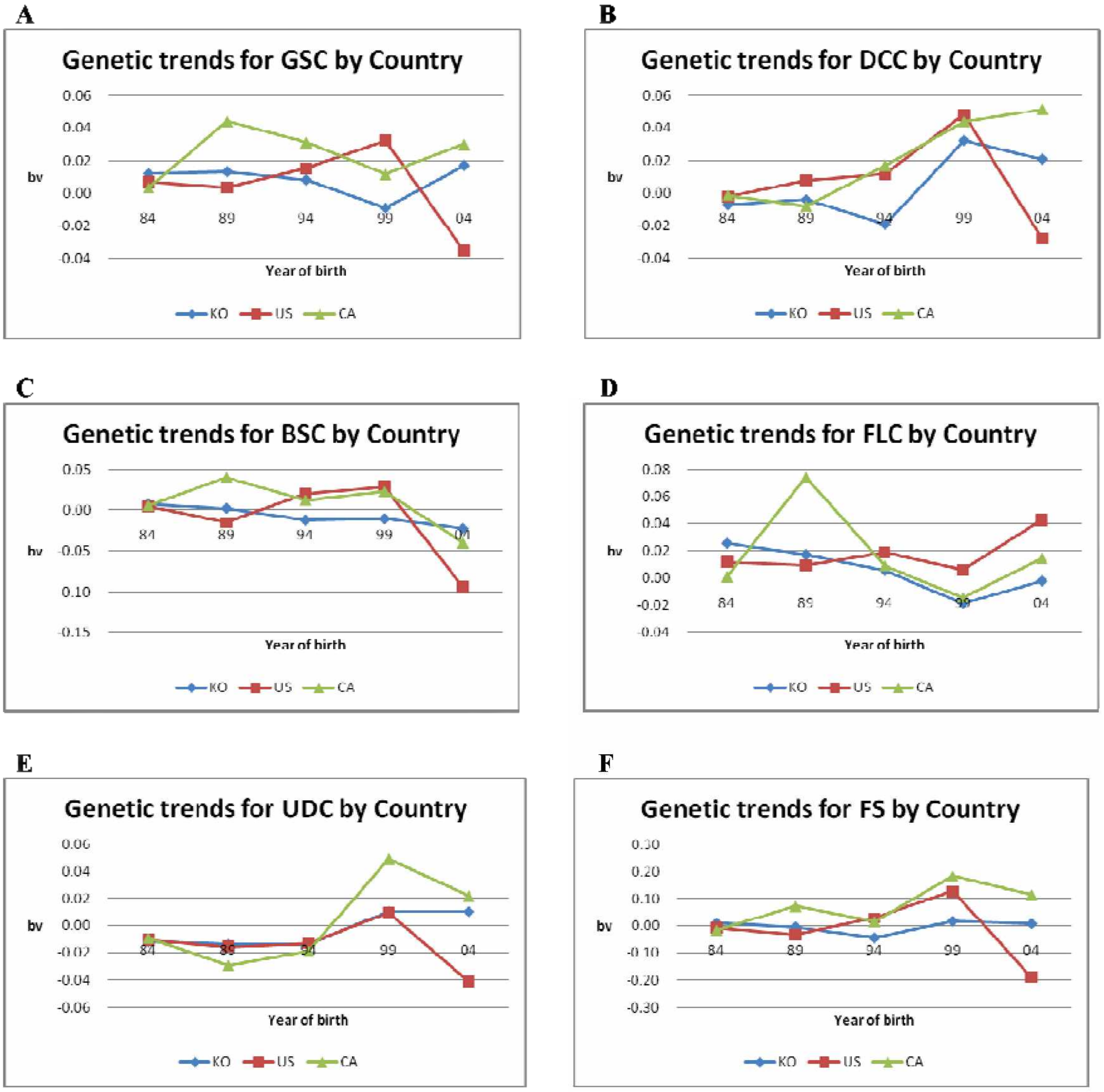

Figure 2. Genetic trends for type scoring traits in Holstein cattle with pedigree sorting by country of origin of sires. Traits analyzed included general stature composite (GSC), dairy capacity composite (DCC), body size composite (BSC), foot and leg composite (FLC) and udder composite (UDC); final scores (FS) were also analyzed.

greater for Canadian lines starting in 1984, and those for USA lines decreased after 1999 (Figure 2F). Overall, these data provide valuable information for scientists and producers involved in genetic selection of dairy cattle in South Korea and, in future years, more analysis should be conducted to continue to follow trends that could impact the dairy industry.

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