Research Article

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Estimation of variance components and genetic parameters for type traits and milk yield in Holstein cattle*

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Abstract: This research was conducted to estimate variance components and genetic parameters for type traits and milk yield in Holstein–Friesian cattle. In this study, 597 daughters of 158 sires in 128 herds were classified. In the data analysis, type scores for 354 daughters bred within 70 herds sired by 46 sires that had at least 3 daughters, and 304 lactation records for 206 daughters within 56 herds sired by 37 sires, were considered. For estimation of variance components and correlations among the traits, the MTDFREML package program was used. The mean stature was 145.56 cm. Means for linear traits varied from 4.47 for fore teat placement to 6.42 for body depth. Heritability for fore udder attachment and front teat placement were both 0.00. Heritability for linear traits estimated for lowest and highest dairy character values and for body capacity were 0.06 and 0.62, respectively. Values for heritability and repeatability of milk yield were 0.20 and 0.20, respectively.

Key words: Holstein–Friesian, type traits, variance components, animal model

Introduction

The primary emphasis in dairy cattle selection is for yield traits because the highest producing cows are usually more profitable (1). In general, profitability can be even higher if cows produce large quantities of milk in routinely initiated lactations while also remaining functionally sound. Selection on yield traits alone could decrease merit for other traits. Selection emphasis on type traits associated with increased herd life may be beneficial in decreasing involuntary culling and increasing profitability (2). One of the primary reasons for collecting and utilizing information on type is to aid breeders in selecting profitable, functional cows so that early culling for causes unrelated to yield (involuntary culling) can be avoided.

Cattle Breeders' Associations were established in Turkey in 1995. In 1998 all local associations were gathered under the Federation of Cattle Breeders' Association (CBAT), and CBAT became a member of the International Committee for Animal Recording (ICAR) in 2000. In the CBAT breeding programs, the weighting values for type traits and milk yield are 0.30 and 0.70, respectively.

* This research was summarized from the PhD dissertation of Serdar Duru.

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Descriptive statistics, variance components, and genetic parameters have been estimated by several researchers, and the relationships between type traits and some economically important traits have been investigated (3–13).

In this study, we report the results of original research from Turkey in which the primary objective was to estimate variance components and genetic parameters for type traits and milk yield in Holstein–Friesian cattle. A second objective was to investigate genetic and phenotypic correlations between milk yield and type traits.

Materials and methods

Data

In this research, in their first 3 lactations, 597 daughters of 158 sires in 128 herds belonging to the Holstein Breeders' Association of Bursa were classified between September 2002 and June 2003. The data used in this study were limited to sires with at least 3 daughters. The type scores of 354 daughters bred within 70 herds sired by 46 sires that had at least 3 daughters and 304 lactation records of 206 daughters within 56 herds sired by 37 sires were considered.

Model and data analysis

In the preliminary analyses, the fixed effects to be included in the model, such as herd, stage of lactation, classification month, and parity × calving age, were found to be significant using a general linear model procedure of the JMP software (14). These effects were determined according to the ICAR guidelines and World Holstein–Friesian Federation standards (15,16). However, an exception to these international criteria was the exclusion of the classifier × herd × visit interaction due to the fact that classification was performed by a single classifier and in some visits fewer than 5 cows were classified.

Descriptive statistics were calculated using Minitab for type traits and milk yield (17). The starting values for the (co)variances were estimated using the LSMLMW package (18).

Variance components and genetic parameters for type traits and 2 × 305-day milk yield were estimated using single-trait analyses with the MTDFREML program in an animal model (19). Genetic and phenotypic correlations between all traits were then estimated using 2-trait analyses.

A general representation of the type traits used in the model is as follows (20):

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Za} + \mathbf{e},$$

where **y** is a vector of type traits and **b** is a vector of fixed effects (e.g., herd) with incidence matrix **X.** The incidence matrix **Z** relates to the random vector of direct genetic effects (**a**) and **e** is a random vector of residual effects.

Permanent environmental effects on milk yield were taken into account by including appropriate uncorrelated random effects in the model. Thus, the following model,

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Za} + \mathbf{Wpe} + \mathbf{e},$$

has some differences from the previous model, in that **y** is a vector of milk yield records and the incidence matrix **W** relates to the uncorrelated random vector of permanent environmental effects (**pe**).

Type traits and measurement scales

Sixteen linear type traits were scored on a scale from 1 to 9, and then other traits of dairy type, body capacity, feet, legs, and udder were scored on a scale from 65 to 100. Stature was measured using a measuring cane. In first and second parity, cows were scored between 65 and 88; in third parity, cows were scored between 65 and 100. The type traits used are shown in Table 1.

Results

Descriptive statistics

Descriptive statistics for the type traits are given in Table 2. Stature varied between 132 and 157 cm, with a mean of 145.56 cm. Linear type trait values and general type trait values varied from 1 to 9 and 65 to 92, respectively. Variation coefficients for stature and general type traits ranged between 2.56% and 4.94%. In addition, other linear trait values and milk yield values varied between 18.74% and 38.89%.

The means of the linear type traits of front teat placement and body depth varied between 4.47 and 6.42, respectively. The means for feet and legs, dairy character, body capacity, and udder were 79.36, 80.81, 81.41, and 80.28, respectively.

Table 1. The relationship between linear and general type traits.

General traits	Linear type traits	Abbreviation	1	9
Dairy type (DT)	Dairy character	DC	Coarse	Angular
Body capacity BC (body)	Stature	Sta	Short	Tall
	Body depth	BD	Shallow	Deep
	Strength (chest width)	Str (CW)	Narrow	Wide
	Rump width	RW	Narrow	Wide
	Rump angle	RA	High pins	Low pins
Feet and legs (F&L)	Rear leg set side view	LSS	Straight	Sickle
	Foot angle	Ft	Low	Steep
	Hocks	HQ	Coarse (roughly)	Slim
	Rear leg set rear view	LSR	Extreme toe-out	Parallel feet
Udder (U)	Fore udder attachment	FUA	Weak	Strong
	Rear udder height	RUH	Very low	Very high
	Suspensory ligament	SL	Broken	Strong
	Udder depth	UD	Deep	Shallow
	Front teat placement	TPf	Wide	Close
	Teat length	TL	Short	Long
	Rear teat placement	TPr	Wide	Close

The linear schemes were established such that the means would approximate 5 and the standard deviations would approximate 1.5. For some traits, notably body depth, rear udder height, and fore udder attachment, the means departed substantially from 5, being 6.42, 6.15, and 6.05, respectively. The standard deviations of some linear traits were much less than 1.5, most notably for suspensory ligament, fore udder attachment, and udder depth.

The mean and standard deviation of the 2 × 305-day milk yield for 304 lactation records were 6010.3 kg and 1323.6 kg, respectively. Milk yield varied from 2613 to 10,718 kg.

Estimation of variance components and genetic parameters for milk yield and type traits

Estimates of variance components, heritabilities, and reliabilities for type traits are presented in Table 2. The additive genetic variances and heritabilities for fore udder attachment and front teat placement were 0.00. The heritabilities for dairy character, rump angle, and udder depth were lower than 0.10. However, for teat length, body depth, stature, and body capacity they were higher than 0.40. The heritabilities of some other traits were found to be at an intermediate level, about 0.20 and 0.25. The heritabilities for feet and legs traits were generally low.

The additive genetic variance, nonadditive genetic variance with permanent environmental variance, residual variance, and phenotypic variance for milk yield were estimated to be 204,924, 260, 794,295, and 999,479, respectively.

The heritability mean ± standard deviation for the 2 × 305-day milk yield was estimated to be 0.20 ± 0.00. Permanent environmental variance was very low. Hence, heritability and repeatability were equal at 0.20 each. The main cause of this result is the fact that we have very little repeated data.

Table 2. Means, standard errors of means (SEM), coefficients of variation (CV) (n = 597), additive genetic variances (σ^2_a), residual variances (σ^2_e) and phenotypic variances (σ^2_p), heritabilities (h^2), standard errors of heritabilities (s_h), reliabilities (r_{AI}), and coefficients of determination (R^2) using models for linear and general type traits and milk yield. In addition, permanent environmental variance (σ^2_{pe}) and repeatability (r) are given for milk yield.

Trait	Mean	SEM	CV (%)	σ^2_a	σ^2_e	σ^2_p	h^2	s_h	r_{AI}	R^2	σ^2_{pe}	r
Sta (cm)	145.56	0.153	2.56	5.798	5.084	10.882	0.53	0.250	0.522	0.272		
DC	5.28	0.055	25.57	0.089	1.468	1.557	0.06	0.138	0.201	0.040		
BD	6.42	0.052	19.63	0.535	0.534	1.069	0.50	0.243	0.508	0.258		
Str	4.61	0.054	28.42	0.236	1.111	1.347	0.18	0.181	0.325	0.106		
RW	4.74	0.042	21.73	0.136	0.701	0.837	0.16	0.219	0.303	0.092		
RA	5.06	0.044	21.15	0.108	1.049	1.157	0.09	0.151	0.256	0.066		
LSS	4.73	0.058	30.02	0.300	1.392	1.692	0.18	0.199	0.322	0.104		
Ft	4.74	0.061	31.65	0.325	1.508	1.833	0.18	0.198	0.323	0.105		
HQ	5.15	0.053	25.24	0.192	1.139	1.331	0.14	0.177	0.298	0.089		
LSR	4.90	0.054	26.94	0.170	1.371	1.541	0.11	0.182	0.260	0.068		
FUA	6.05	0.073	29.42	0.000	2.258	2.258	0.00	0.164	0.000	0.000		
RUH	6.15	0.058	22.93	0.209	1.193	1.402	0.15	0.176	0.309	0.096		
SL	5.40	0.086	38.89	1.035	2.896	3.931	0.26	0.193	0.400	0.160		
UD	5.48	0.069	30.66	0.184	1.813	1.997	0.09	0.164	0.245	0.060		
TPf	4.47	0.043	23.49	0.000	0.785	0.785	0.00	0.143	0.000	0.000		
TL	5.55	0.042	18.74	0.443	0.533	0.976	0.45	0.226	0.496	0.246		
TPr	5.17	0.047	22.24	0.120	1.072	1.192	0.10	0.175	0.258	0.067		
DT	80.62	0.124	3.76	1.821	5.482	7.303	0.25	0.208	0.374	0.140		
BC	81.51	0.165	4.94	7.555	4.569	12.124	0.62	0.250	0.562	0.316		
F&L	79.78	0.158	4.83	1.626	10.378	12.004	0.14	0.201	0.282	0.079		
U	80.20	0.159	4.84	1.347	9.845	11.192	0.12	0.218	0.261	0.068		
Milk	6010.3	75.88	22.01	204,924	794,295	999,479	0.20	0.000	0.335	0.113	260	0.20

Sta = stature, DC = dairy character, BD = body depth, Str = strength (chest width), RW = rump width, RA = rump angle, LSS = rear leg set side view, Ft = foot angle, HQ = hocks, LSR = rear leg set rear view, FUA = fore udder attachment, RUH = rear udder height, SL = suspensory ligament, UD = udder depth, TPf = front teat placement, TL = teat length, TPr = rear teat placement, DT = dairy type, BC = body capacity, F&L = feet and legs, U = udder.

Genetic and phenotypic correlations between type traits

Genetic correlations among type traits ranged from −1.0 to 1.0 (Table 3).

The genetic correlations were generally higher than the phenotypic correlations. The highest phenotypic correlations were between stature and body capacity, suspensory ligament and fore udder attachment (0.78), and front teat placement and teat length (−0.50). Most other phenotypic correlations were low.

Genetic and phenotypic correlations between type traits and milk yield

Genetic correlations between milk yield and the type traits ranged from −0.13 for udder depth to 1.00 for udder and feet and legs (Table 3). Nine traits had genetic correlations with milk yield greater than 0.20 (absolute value) and only 5 traits had genetic correlations with yield greater than 0.30.

Phenotypic correlations between milk yield and type traits ranged from −0.19 for udder depth to 0.31 for hocks (Table 3).

Table 3. Genetic and phenotypic correlations between type traits and milk yield.

Genetic correlations																						
Trait	**Sta**	**DC**	**BD**	**Str**	**RW**	**RA**	**LSS**	**Ft**	**HQ**	**LSR**	**FUA**	**RUH**	**SL**	**UD**	**TPf**	**TL**	**TPr**	**DT**	**BC**	**F&L**	**U**	**Milk**
Sta		−0.07	0.67	1.00	1.00	−0.81	0.12	0.57	−0.60	−0.45	0.31	0.04	−0.53	−0.47	−1.00	0.02	−0.74	0.72	0.94	0.38	−0.99	0.14
DC	0.08		−0.41	0.70	−1.00	0.64	−0.65	0.51	0.97	0.83	−1.00	0.63	−1.00	−1.00	−1.00	0.09	−1.00	0.37	0.56	0.54	0.22	0.21
BD	0.22	−0.10		0.49	0.94	−0.99	0.01	0.89	−0.49	−0.65	−0.05	−0.91	−0.41	−1.00	−1.00	−0.02	−0.77	0.25	0.76	0.49	−0.48	0.13
Str	−0.06	−0.15	0.12		0.32	0.18	0.59	−0.54	−0.75	0.41	−0.54	0.39	0.64	0.55	0.50	0.30	0.53	0.55	0.82	−0.29	0.26	0.24
RW	0.17	−0.08	0.08	0.22		−0.70	0.77	0.75	−0.53	−0.97	0.88	0.32	−0.20	−0.40	0.17	0.34	0.00	0.05	0.30	0.09	0.00	0.19
RA	−0.22	−0.02	−0.05	0.00	−0.16		−0.06	−0.76	0.43	1.00	1.00	−1.00	0.13	0.83	1.00	0.02	1.00	−0.61	−0.90	0.43	0.79	−0.04
LSS	−0.11	−0.04	0.07	0.19	0.18	0.04		−0.40	−0.99	−1.00	−0.04	1.00	−0.01	−0.60	−0.61	0.39	−0.57	−0.59	−0.23	−0.83	0.36	0.25
Ft	0.20	0.02	0.12	−0.15	−0.05	−0.11	−0.39		0.21	0.47	−0.03	−0.87	−0.30	0.23	−1.00	−0.55	0.24	1.00	0.94	0.96	−0.63	0.58
HQ	−0.11	0.20	−0.07	−0.08	−0.43	0.06	−0.07	0.02		0.72	−0.94	−0.79	−0.61	−0.12	−0.24	0.20	−0.71	−0.58	−0.77	−0.47	−0.50	−0.09
LSR	0.03	0.05	0.01	0.05	−0.07	−0.02	−0.37	0.13	−0.41		0.67	0.39	−0.16	0.98	−0.03	0.19	0.98	0.34	−0.22	0.25	0.27	0.05
FUA	0.09	0.10	−0.10	−0.02	−0.19	−0.11	−0.06	−0.20	−0.10	0.02		0.99	1.00	1.00	−0.10	−1.00	1.00	−0.68	−1.00	−0.77	0.99	0.15
RUH	0.01	0.05	−0.08	0.14	−0.09	0.01	−0.06	0.09	−0.09	0.18	0.09		0.37	0.86	1.00	0.27	0.76	0.34	−0.13	−1.00	0.59	0.64
SL	0.03	0.14	−0.17	0.00	0.07	−0.14	−0.17	0.14	−0.03	−0.05	0.15	0.51		1.00	0.06	−0.17	1.00	−0.73	−0.56	−0.13	0.04	0.00
UD	0.16	0.27	−0.32	−0.01	−0.14	−0.08	−0.21	0.05	0.11	0.06	0.55	0.03	0.55		1.00	−0.33	0.95	0.07	−0.29	−0.33	−0.37	−0.13
TPf	−0.10	0.12	−0.23	−0.06	−0.30	−0.29	−0.01	−0.12	−0.05	−0.06	0.00	0.60	0.78	0.74		−1.00	1.00	−1.00	−1.00	−1.00	−0.99	−0.01
TL	0.05	−0.08	0.07	0.08	0.20	−0.02	−0.03	0.00	−0.08	−0.06	−0.11	0.14	−0.02	−0.18	−0.50		0.10	−0.17	0.09	−1.00	−0.02	−0.02
TPr	0.00	0.04	−0.05	−0.02	−0.44	0.03	−0.01	−0.06	0.02	0.07	0.25	0.30	0.12	0.23	0.21	−0.12		−0.11	−0.86	−0.43	1.00	0.04
DT	0.35	0.60	0.13	−0.08	−0.17	−0.10	−0.14	0.18	0.05	0.12	0.14	0.52	0.11	0.11	0.13	0.04	0.05		0.97	1.00	−0.01	0.39
BC	0.78	0.03	0.52	0.03	0.17	−0.22	−0.03	0.18	−0.13	0.10	0.04	0.16	−0.05	0.01	−0.04	0.12	0.02	0.39		0.79	−0.47	0.07
F&L	0.28	0.04	0.27	0.15	−0.17	−0.05	−0.36	0.43	−0.01	0.26	0.13	0.47	0.15	0.11	0.03	0.00	0.08	0.44	0.44		−0.89	1.00
U	0.07	0.10	−0.03	0.02	−0.14	−0.09	−0.15	0.00	−0.11	0.08	0.52	0.36	0.40	0.41	0.03	−0.13	0.19	0.26	0.10	0.27		1.00
Milk	0.05	0.02	0.21	0.00	0.08	−0.10	0.04	0.08	0.31	0.12	0.00	0.22	0.03	−0.19	−0.02	−0.08	0.24	0.08	0.16	0.00	0.04	
Phenotypic correlations																						

Discussion

The means for front teat placement obtained in this study are well within the scope of results reported in the literature (3,5,8), but are higher than those reported by Klassen et al. (7).

Milk yield was higher than the values reported by others: 5592 kg for 22,295 lactation records from Turkey by Kumlu and Akman (21) and 5739 kg for 4008 lactation records from Bursa by Özcan and Terlemez (22).

Many researchers, similar to the findings of this study, have reported the heritability of stature to be higher than that of the other type traits (3,7,8,11,12,23, 24–29).

Mainly due to the limited number of records, correlations among some traits were low and the standard errors of the genetic correlations were high.

Meyer et al. (3) reported genetic correlation values between type traits in the first lactation from –0.75 (LSS–LSR; see Tables for these and following abbreviations) to 0.76 (Str–BD), and in the second lactation from –0.65 (DC–Str) to 0.78 (BD–Str). DeGroot et al. (12) obtained genetic correlations between type traits ranging from –0.86 (RA–Ft) to 1.00 (Str–RW). Genetic correlations reported by other authors were 0.097 for BD–wither height (4), 0.97 for Sta–BD (7), and 0.92 for Str–BD (5). Generally, some phenotypic correlations in this study were lower than those in other studies (3,5,7,8).

While some of the genetic correlations reported in this study were similar to those reported in the literature (3,5–8,12), some were higher than the values reported by other researchers.

Meyer et al. (3) reported genetic correlations ranging from –0.52 to 0.24 between linear type scores and milk yield in primiparous British Friesians. Udder depth and fore udder attachment had the largest negative correlations with yield (–0.52 and –0.37, respectively). The corresponding phenotypic correlations were smaller in magnitude and ranged from –0.27 to 0.21. The genetic correlation between milk yield and final score in first parity was –0.14.

Misztal et al. (6) reported genetic correlations between milk yield and type traits ranging from –0.44 for udder depth to 0.59 for dairy form. Short and Lawlor (5) calculated genetic correlations between the first lactation milk yield and the type traits for registered cows as –0.48 for udder depth to 0.54 for dairy form. They also reported that the daughters of bulls siring the highest yielding cows had deeper udders with looser fore udder attachments and sloping rumps.

Meyer et al. (3) reported phenotypic correlations between type scores and milk yield lower than 0.30. Klassen et al. (7) calculated generally low and positive phenotypic correlations between lifetime yield and type traits. The highest phenotypic correlation was estimated between milk yield and dairy type. The phenotypic correlation between milk yield and udder depth obtained by Rogers (30) was –0.20.

This research was conducted to estimate variance components and genetic parameters for the type traits and milk yield in Holstein–Friesian cattle. In addition, genetic and phenotypic correlations between milk yield and type traits were estimated. These results are expected to aid in breeding programs under the auspices of CBAT.

Estimates of heritability for type traits using an animal model were moderately low. Genetic correlations between yield and some type traits were negative, suggesting that continuous selection for milk yield could cause deterioration in some conformational traits.

Research to utilize multitrait indices in Turkey includes: 1) determining the economically important traits (e.g., fat, protein, somatic cell count, longevity, and reproductive performance), their variances, heritabilities, and relationships to milk yield, and 2) developing economic methods to combine genetic information for multiple traits into a useful sire selection index. Therefore, it would be useful to evaluate sires with a multitrait index in Turkey, combining milk yield and other economically important characters such as somatic cell count and reproductive traits.

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