

Adjustment of Lactation Number and Stage on Informal Linear Type Traits of Holstein Dairy Cattle

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ABSTRACT

A total of 4,323,781 records for informal 16 primary linear descriptive traits of dairy cows in Holstein breed from 1988 to 2007 in USA were analyzed to estimate adjustment factors for lactation number and stage. While all factors in the model were highly significant ($P < 0.01$), major influences on linear type traits were due to lactation number and stage. The frequencies of lactation number 1 through 6 were 58.6, 22.0, 11.8, 4.8, 2.1, and 0.8%, respectively. Further, the frequencies of lactation stage were 0.7, 76.9, 15.3, 4.9, and 2.1%, respectively, for springing, early, medium, late, and dry. To adjust 16 linear traits (stature, dairy form, strength, body depth, rump width, rump angle, legs rear view, leg set, foot angle, fore udder, rear udder height, rear udder width, udder support, udder depth, and front teat placement), additive and multiplicative adjustment factors of lactation number (lactations 2 to 4) and stage (springing, medium, late and dry) were estimated with the solutions in the generalized linear model, assigning lactation 1 and stage early as base class. Additive adjustment factors of lactation number ranged from -1.23 to 2.908 , while multiplicative factors ranged from 0.853 to 2.207 . Further, additive and multiplicative adjustment factors for lactation stage ranged from -0.668 to 0.785 , and from 0.891 to 1.154 . Application of adjustment factors to 20 randomly sampled sub-data sets produced the results that additive adjustment factors for both lactation number and stage reduced more mean square of lactation number and stage over 16 linear traits than any combination of adjustments, and led additive adjustment factors for both lactation number and stage as a choice of methods for adjustment of informal 16 primary linear type traits collected by classifiers of AI studs.

(Key words : Informal linear traits, Additive, Multiplicative, Adjustment, Dairy cattle)

INTRODUCTION

Classification program on the conformation traits in dairy cattle helps farmers to make management decision and to add value to their cattle. Identifying profitable and valuable animals can be obtained from the information of type trait classification such as higher producing and more durable cows (Norman et al. 1996). Each breed association of dairy cattle in USA provides linear type classification program for the registered cows. The AI studs also provide farmers linear type trait appraisal of cows. Linear type traits of economic importance to dairy producers are measured at times conducive to the effective use of labor and breeding cows and are, therefore, performed over a wide range of physical conditions. However, accurate methods to adjust for variation

due to lactation number and stage are needed to standardize linear type traits (Moeller et al., 1998), which would be used to help farmer for mating decision. The classifiers recommend proper semen to farmers with evaluation of cows by recording device. Production records of dairy cattle are standardized to account for the effects of age at calving and lactation (Khan and Shook, 1996 Wiggans and Dickinson, 1985). After adjustment for age and stage of lactation on linear type traits, genetic evaluation is carried out (Vanraden et al., 1990). Higher variation due to lactation number and stage in linear traits masks real superiority of cows, and therefore, farmers are not able to make decisions on choosing appropriate semen for cows. The objectives of this study were to develop adjustment factors of informal linear type traits for practical use.

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MATERIALS AND METHODS

1. Data

A total of 4,323,781 records on 16 primary linear descriptive traits of dairy cows were collected by AI stud classifiers from 1988 to 2007 in the U.S. The data were edited for missing information on herd, date of evaluation and bull identification and lactation stage. Data available after editing were 4,011,811 records of Holstein breed. The numbers of record was presented in Table 1. Linear type traits were scored by the classifiers from AI studs with scale of 1 to 9

Table 1. Numbers of records and levels in the data

Source	Holstein
Herd	10,884
Bull	9,687
AI stud	456
Classifier	155
Year-month	112
Number ^a	6
Stage ^b	5
No. of record	4,011,811

^a and ^b represent lactation number and stage.

points. The linear type traits consisted of form (stature, dairy form, strength and body depth), rump (rump width and rump angle), leg and feet (legs rear view, leg set and foot angle), udder (fore udder, rear udder height, rear udder width, udder support and udder depth) and teats (front teat placement and teat length), as shown in Table 2.

2. Statistical analysis

Data from the 16 linear type traits were analyzed by the GLM procedure of SAS as specified in the model below.

$$y_{ijklmn} = m + h_i + b_j + cl_k + cym_l + lac_m + stg_n + e_{ijklmn}$$

where y_{ijklmn} is linear type score of cow, m is overall mean, h_i is i^{th} herd effect, b_j is effect of j^{th} bull, cl_k is the effect of k^{th} classifier, cym_l is the effect of l^{th} classification year-month, lac_m is the effect of m^{th} lactation (1 to 6), stg_n is the effect of n^{th} stage of the lactation, and e_{ijklmn} is a residual random effect. Lactation stages were classified to springing, early, medium, late and dry during a lactation period of the cows. Parity groups ranged from 1 to 6. Classifier and appraisal year month were included in the model, of which information was collected by classifiers from AI studs. To account for differences in genetic merit of sires, sires were included in the model.

Adjustment factors were computed from the solutions for

Table 2. Mean squares¹⁾ of the factors and means in 16 primary linear descriptive traits in Holstein cows

Trait	Mean square							Mean	STD
	Herd	Bull	Classifier	YM	LN	LS	Error		
Stature (ST)	80.1	29.6	326.4	74.4	57,556.7	5,319.2	1.4	5.65	1.38
Dairy form (DF)	69.1	25.6	370.4	49.9	28,572.9	18,068.4	1.5	5.88	1.39
Strength (SR)	39.4	18.4	131.5	63.9	39,865.2	15,302.2	1.3	5.44	1.28
Body depth (BD)	71.7	21.1	235.5	31.5	71,983.9	6,092.4	1.3	5.56	1.30
Rump width (RW)	71.0	18.5	261.0	48.1	37,815.2	6,247.1	1.2	5.42	1.28
Rump angle (RA)	67.5	14.2	408.4	53.4	4,759.6	1,352.0	1.1	5.35	1.18
Legs rear view (LR)	56.7	14.9	290.7	45.4	10,254.0	801.6	1.2	5.79	1.24
Leg set (LS)	69.2	14.6	260.8	64.3	5,867.9	650.0	1.5	4.89	1.37
Foot angle (FA)	109.2	28.3	316.4	168.9	36,934.3	2,665.6	1.7	5.09	1.49
Fore udder (FU)	77.9	20.2	620.6	188.8	10,544.5	2,366.0	1.4	5.45	1.33
Rear udder height (UH)	101.8	22.4	386.6	151.9	34,092.9	789.1	1.4	5.34	1.35
Rear udder width (UW)	96.9	33.5	372.9	55.3	25,379.5	5,695.2	2.0	5.67	1.56
Udder support (US)	137.6	60.6	364.6	81.9	423,335.0	276.3	1.5	5.32	1.68
Udder depth (UD)	69.9	33.7	216.0	65.1	4,721.7	4,481.9	2.0	5.23	1.54
Front teat placement (FT)	84.4	15.8	575.7	132.7	1,710.8	3,528.7	1.7	5.17	1.45
Teat length (TL)	85.3	25.1	487.2	116.9	31,968.5	611.8	1.7	4.77	1.44

¹⁾ Highly significant ($P < 0.01$) for lactation number and stage for all traits; YM stands for year and month of classification; LN and LS represents lactation number and stage, respectively.

lactation number and stage (Khan and Shook, 1996). Additive adjustment factors (a_i) were obtained as

$$a_i = c_i - c_0$$

and multiplicative adjustment factors were obtained as

$$m_i = (\mu + c_0) / (\mu + c_i)$$

where c_0 is solution for the base class of lactation number or stage; c_i is solution for class i of lactation number or stage; and μ is overall mean. The chosen base classes were lactation 1 for the lactation number and stage early for the lactation stage.

Twenty sub-data sets were randomly sampled from the entire Holstein records. Each of randomly sampled sub-data consisted approximately 5% of the entire Holstein records. Estimated adjustment factors were applied to 20 sub-data sets, and then, the analysis was conducted to verify the adjustment factors. Four different ways of applying adjustment factor to the data sets were adopted. Firstly, additive adjustment factors of lactation number and stage were added to records according to proper lactation number and stage (record + a_N + a_S), which was denoted by a_{NAS} . Secondly, multiplicative adjustment factors of lactation number and stage were multiplied to records according to proper lactation number and stage (record $\times m_N \times m_S$), which was denoted by m_{NMS} . Thirdly, multiplicative adjustment factors of lactation stage was multiplied to records and then, added additive adjustments of lactation number (record $\times m_S$ + a_N), which was denoted by a_{NMS} . Finally, multiplicative adjustment factors of lactation number was multiplied to records and then, added additive adjustments of lactation stage (record $\times m_N$ + a_S), which was denoted by m_{NAS} . In the abbreviations, letter a and m represent additive and multiplicative adjustment factors, respectively, subscript N and S represent lactation number and stage, respectively.

RESULTS AND DISCUSSION

Data collected by AI stud classifiers were less informative than those by classifiers of the breed associations in the United States. The information of pedigree and the entity for cows were usually not collected, since type evaluation by classifiers of AI studs is conducted only for choosing appropriate semen to inseminate cows in herds. The effects of herd, bull, classifier, evaluation year month, lactation number and stage for linear type traits were significant at level of $P < 0.01$, using F -test, as shown in Table 2. Variations due to classifiers were fairly large, comparing with

mean squares of herd, and bull. It seemed to be scoring error made by classifiers, and should be lessened with training and calibrating techniques for visual assessment. The variations due to classifier can be removed in the genetic evaluation, including classifier in the model as fixed. Major influences on linear type traits were due to lactation number and stage, differently from classifier in Holstein dairy cattle in Korea (Song et al., 2002). However, type traits collected in Korea had scale 1 to 50 points instead of scale 1 to 9 points, and generally detected more variation due to classifier (unpublished). Most of the linear traits had the largest mean squares in lactation number in Table 2. Influences on linear type traits by lactation number reflect physiological condition rather than genetic superiority of cows, since lactation number was apparently another expression of cows' age (Royal et al., 2002). For instance, score of udder support reflects the median suspensory ligament of udder, the primary support for udder. As number of lactation increases, the ligament would be exhausted and lower score is assigned in classification. Consequently, largest mean squares due to lactation number were shown in traits of udder support following body depth, stature and strength. Norman and Cassell (1978) reported that variations in linear type traits were greatly influenced by ageing of cows. The second largest mean squares for the linear traits except front teat placement were observed in lactation stage. Lactation stage reflected estrous cycle of dairy cows. During the lactation of about 10 month period, body condition of cows is influenced dramatically corresponding to milk secretion, and therefore, the scores of linear type traits are changed correspondingly (Landete-Castillejos and Gallego, 2000). Dairy form, strength, rump width, body depth and rear udder width had large mean squares due to lactation stage. Less influence on traits of leg due to lactation stage was detected. While the traits of rump angle, udder depth and front teat placement were less affected by lactation number, small variations on udder support and teat length were discovered in lactation stage.

Generally lactation number gave more influence on the traits than lactation stage did as presented in Table 2. Both influences of lactation number and stage, however, were not relevant to genetic superiority of cows and should be removed by adjustment to properly evaluate cows (Cruickshank et al. 2002). Size of mean squares seemed to be different as size of data changed. However, there were many similar trends in size of mean squares of linear type traits among breeds (no data provided). While mean squares of lactation

number in udder support were largest overall, mean squares of stage in udder support were rather small. Among mean squares of lactation stage, dairy form showed largest in most breeds. These tendencies were mostly due to physical reflection being relevant to linear type traits such that influences of age and lactation stage were different according to traits.

Frequency of Holstein data according to lactation number and stage were presented in Table 3. The frequencies for the lactation stages of springing, early, medium, late and dry were 0.72, 76.94, 15.32, 4.93 and 2.09%, respectively. Fewer records were categorized into stage of springing and dry, which had obvious threshold between categories. The categories of early, medium and late were inclined to intuition of classifiers, which were rather ambiguous. However, it was assumed that the stages of early, medium and late included 0 to 3 months, 4 to 6 months and 7 months or over, respectively. The percentages of lactation 1

to 6 were 58.57, 21.96, 11.81, 4.78, 2.12 and 0.76%, respectively. Once type evaluation was undergone for a cow, the cow did not need more type evaluation in the next lactations. Consequently, the rate of decreasing over lactations was more sharply down comparing to the rate of aged cows at farm (Miller et al., 2008). The largest group of lactation 1 and stage early were assigned as base classes for adjustment factors, which were largest in number of records (Song et al., 2002).

The means of lactation number and stage compared, using Duncan's multiple range test in Table 4. In all linear type traits, means of adjacent lactations were generally similar values with adjacent means, which were noted by alphabets with descending order in superscripts. The traits of rump angle, fore udder, rear udder height, and front teat placement showed less change in means over lactations than other traits. Differences of means in lactation 4 to 6 generally were smaller than those in lactation 1 to 3 in all traits

Table 3. Frequency of linear trait records according to lactation number and stage in Holstein cows

Lactation stage	Lactation number						%	Frequency
	1	2	3	4	5	6		
Springing	0.61	0.05	0.03	0.01	0.01	0.00	0.72	28,769
Early	46.95	16.82	8.08	3.35	1.49	0.55	76.94	3,086,714
Medium	8.32	3.33	2.29	0.88	0.37	0.12	15.32	614,499
Late	2.29	1.15	0.92	0.35	0.17	0.05	4.93	197,782
Dry	0.71	0.60	0.49	0.18	0.09	0.03	2.09	84,047
%	58.57	21.96	11.81	4.78	2.12	0.76	100.00	
Frequency	2,349,865	880,981	473,932	191,687	84,878	30,468		4,011,811

Table 4. Least square means of lactation number and stage in 16 linear traits of Holstein cows

		Trait ¹⁾															
		ST	DF	SR	BD	RW	RA	LR	LS	FA	FU	UH	UW	US	UD	FT	TL
Lactation number	1	5.39 ^f	5.72 ^f	5.25 ^f	5.31 ^f	5.21 ^f	5.46 ^a	5.67 ^f	5.01 ^a	5.28 ^a	5.36 ^c	5.18 ^e	5.80 ^a	6.03 ^a	5.25 ^b	5.20 ^a	4.58 ^f
	2	5.94 ^e	6.07 ^e	5.50 ^e	5.73 ^e	5.52 ^e	5.24 ^b	5.86 ^e	4.77 ^b	4.97 ^b	5.60 ^b	5.56 ^c	5.70 ^b	4.80 ^b	5.31 ^a	5.20 ^a	4.85 ^e
	3	6.04 ^d	6.10 ^d	5.85 ^d	6.01 ^d	5.86 ^d	5.15 ^{cd}	6.03 ^d	4.70 ^c	4.76 ^c	5.52 ^d	5.58 ^b	5.40 ^c	4.05 ^c	5.15 ^c	5.10 ^b	5.08 ^d
	4	6.21 ^a	6.18 ^c	6.09 ^b	6.30 ^c	6.09 ^b	5.14 ^e	6.14 ^c	4.64 ^d	4.57 ^d	5.53 ^d	5.64 ^a	5.10 ^d	3.48 ^d	5.00 ^d	5.00 ^c	5.19 ^c
	5	6.19 ^b	6.30 ^b	6.14 ^a	6.46 ^b	6.10 ^a	5.16 ^c	6.27 ^b	4.57 ^e	4.44 ^e	5.56 ^c	5.55 ^c	4.96 ^e	3.14 ^e	4.91 ^e	4.93 ^d	5.25 ^a
	6	6.08 ^c	6.38 ^a	6.05 ^c	6.49 ^a	6.01 ^c	5.15 ^{de}	6.29 ^a	4.47 ^f	4.40 ^f	5.61 ^a	5.40 ^d	4.86 ^f	2.96 ^f	4.86 ^f	4.82 ^e	5.24 ^b
Lactation stage	Springing	5.70 ^c	5.55 ^d	5.75 ^c	5.82 ^c	5.52 ^c	5.24 ^b	5.57 ^c	4.80 ^c	5.32 ^d	5.37 ^c	4.97 ^d	5.61 ^c	5.81 ^a	4.70 ^e	5.25 ^a	4.84 ^c
	Early	5.61 ^e	5.88 ^b	5.38 ^e	5.49 ^e	5.36 ^c	5.40 ^a	5.77 ^d	4.92 ^a	4.99 ^e	5.44 ^b	5.34 ^b	5.58 ^d	5.31 ^c	5.17 ^d	5.18 ^b	4.69 ^d
	Medium	5.67 ^d	6.02 ^a	5.47 ^d	5.72 ^d	5.49 ^d	5.24 ^b	5.86 ^c	4.81 ^b	5.39 ^b	5.51 ^a	5.33 ^{bc}	5.98 ^a	5.36 ^b	5.43 ^b	5.15 ^c	4.92 ^b
	Late	5.99 ^b	5.47 ^e	6.02 ^a	5.96 ^b	5.87 ^b	5.18 ^c	5.90 ^b	4.77 ^d	5.50 ^a	5.35 ^d	5.36 ^a	5.99 ^a	5.17 ^d	5.55 ^a	5.12 ^d	5.00 ^a
	Dry	6.04 ^a	5.76 ^c	6.00 ^b	6.13 ^a	5.97 ^a	4.98 ^d	6.06 ^a	4.66 ^e	5.35 ^c	5.51 ^a	5.33 ^c	5.87 ^b	5.04 ^e	5.27 ^c	4.99 ^e	4.91 ^b

The values followed by the same superscript (^{a,b,c,d,e} and ^f) in same column do not differ significantly ($P > 0.05$) and alphabets of superscripts represent order in size; ST=stature; DF=dairy form; SR= strength; BD=body depth; RW= rump width; RA=rump angle; LR=legs rear view; LS=leg set; FA=foot angle; FU=fore udder; UH=rear udder height; UW=rear udder width; US=udder support; UD=udder depth; FT=front teat placement; TL=teat length.

except fore udder and rear udder heights. Considering the frequencies, the differences of means over lactations, and practical convenience, lactation 4 to 6 were considered as a group.

Adjustment factors were estimated with solutions of lactation number and stage in generalized linear model, as shown in Table 5. Registered cows usually keep the information on their calving and birth date. However, the classifiers, collecting data used in this study, from AI studs rarely had chance to access the information. Consequently, it

was unavoidable that coarse information of cows limited approaches for estimating adjustment factors. Estimates of additive and multiplicative adjustment factors for the base classes were 0 and 1, respectively, which were lactation number 1 and lactation stage early, and not shown in the table. Additive adjustment factors of lactation number ranged from -1.230 to 2.908 , while multiplicative factors ranged from 0.853 to 2.207 . Further, additive and multiplicative adjustment factors for lactation stage ranged from -0.668 to 0.785 , and from 0.891 to 1.154 . For lactation number,

Table 5. Adjustment factors of 16 linear traits for lactation number and stage in Holstein cows

Trait		Lactation number			Lactation stage			
		2	3	4 or over	Springing	Medium	Late	Dry
Additive factor	Stature	−0.573	−0.822	−0.926	−0.275	−0.129	−0.398	−0.367
	Dairy form	−0.472	−0.496	−0.616	0.418	0.144	0.785	0.515
	Strength	−0.270	−0.665	−0.936	−0.644	−0.169	−0.668	−0.586
	Body depth	−0.513	−0.859	−1.230	−0.483	−0.170	−0.352	−0.461
	Rump width	−0.363	−0.671	−0.851	−0.342	−0.101	−0.411	−0.433
	Rump angle	0.181	0.239	0.227	0.217	0.073	0.154	0.240
	Legs rear view	−0.178	−0.327	−0.464	0.059	−0.098	−0.041	−0.172
	Leg set	0.145	0.259	0.334	0.108	0.075	0.059	0.183
	Foot angle	0.234	0.578	0.943	0.032	−0.148	−0.282	−0.169
	Fore udder	−0.334	−0.261	−0.196	0.204	0.109	0.284	0.115
	Rear udder height	−0.499	−0.606	−0.625	0.141	0.055	0.137	0.160
	Rear udder width	0.020	0.374	0.788	0.221	−0.284	−0.281	−0.213
	Udder support	1.281	2.131	2.908	−0.054	−0.035	−0.089	−0.088
	Udder depth	−0.104	0.066	0.264	0.472	−0.188	−0.268	−0.021
	Front teat placement	−0.027	0.083	0.176	0.045	0.200	0.220	0.353
	Teat length	−0.366	−0.601	−0.773	−0.085	−0.079	−0.060	0.085
Multiplicative factors	Stature	0.908	0.873	0.859	0.954	0.978	0.934	0.939
	Dairy form	0.926	0.922	0.905	1.077	1.025	1.154	1.096
	Strength	0.953	0.891	0.853	0.894	0.970	0.891	0.903
	Body depth	0.916	0.866	0.819	0.920	0.970	0.940	0.923
	Rump width	0.937	0.890	0.864	0.941	0.982	0.930	0.926
	Rump angle	1.035	1.047	1.044	1.042	1.014	1.030	1.047
	Legs rear view	0.970	0.947	0.926	1.010	0.983	0.993	0.971
	Leg set	1.031	1.056	1.073	1.023	1.016	1.012	1.039
	Foot angle	1.048	1.128	1.227	1.006	0.972	0.947	0.968
	Fore udder	0.942	0.954	0.965	1.039	1.020	1.055	1.022
	Rear udder height	0.915	0.898	0.895	1.027	1.010	1.026	1.031
	Rear udder width	1.004	1.071	1.161	1.041	0.952	0.953	0.964
	Udder support	1.317	1.669	2.207	0.990	0.993	0.984	0.984
	Udder depth	0.980	1.013	1.053	1.099	0.965	0.951	0.996
	Front teat placement	0.995	1.016	1.035	1.009	1.040	1.044	1.073
	Teat length	0.928	0.888	0.860	0.982	0.984	0.988	1.018

Table 6. Averages and standard deviations of mean squares of lactation number and stage in 20 sub-data set according to different applications of adjustment

Trait	$a_N a_S$				$m_N m_S$				$a_N m_S$				$m_N a_S$			
	Lactation		Stage		Lactation		Stage		Lactation		Stage		Lactation		Stage	
	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.
Stature	1.8	1.3	1.7	1.3	24.1	5.2	1.9	1.4	1.9	1.2	3.1	2.1	27.4	5.6	1.7	1.3
Dairy form	2.5	2.0	4.7	2.0	3.6	2.4	2.2	1.3	3.2	2.3	6.2	2.7	3.1	2.3	3.6	1.5
Strength	1.9	1.9	2.1	1.5	8.8	3.8	2.1	1.4	1.8	2.0	5.5	2.5	13.2	4.9	2.2	1.6
Body depth	5.9	3.4	1.3	1.1	48.4	9.3	1.2	0.8	6.1	3.5	2.0	1.6	55.1	10.3	1.0	0.8
Rump width	2.1	1.2	1.7	1.4	6.0	2.1	1.6	1.3	2.2	1.4	2.8	1.6	7.8	2.4	1.8	1.6
Rump angle	1.2	0.9	1.5	1.4	1.6	1.1	1.7	1.6	1.2	0.9	1.5	1.6	1.7	1.2	1.4	1.3
Legs rear view	1.8	1.7	1.1	0.6	2.0	2.1	1.0	0.5	1.8	2.1	1.0	0.6	2.2	2.1	1.0	0.5
Leg set	2.3	1.8	1.8	1.0	2.2	1.9	1.9	1.0	2.3	2.1	1.8	0.8	2.1	1.9	1.9	1.0
Foot angle	3.0	2.4	1.3	1.1	8.4	5.6	1.6	1.2	3.0	2.5	1.5	1.7	7.1	5.3	1.7	1.2
Fore Udder	1.6	1.3	1.7	0.9	1.8	1.5	1.6	1.0	1.7	1.0	2.2	1.2	1.7	1.5	1.6	1.0
Rear udder height	3.9	2.6	1.6	1.0	16.7	6.0	1.5	0.9	3.8	2.9	1.9	1.2	16.0	5.8	1.3	0.8
Rear udder width	2.3	1.4	3.3	2.2	2.9	1.7	3.1	2.0	2.4	1.4	3.2	1.7	3.3	2.3	3.1	2.1
Udder support	5.1	2.6	3.3	1.6	2320.7	87.7	25.9	7.9	5.1	3.0	2.2	1.1	2280.8	91.7	23.0	6.9
Udder depth	2.8	2.2	2.3	1.0	2.9	2.2	2.0	0.9	2.9	1.7	2.2	1.2	2.9	2.4	2.4	1.1
Front teat placement	2.6	2.2	2.3	1.9	2.7	2.6	2.9	2.3	2.7	2.7	2.9	2.4	2.7	2.4	2.5	1.9
Teat length	2.7	2.5	1.9	1.1	13.6	5.7	1.6	0.9	2.7	2.1	2.0	1.2	14.3	5.9	1.7	1.0

Adjustments of records, $a_N a_S$, $m_N m_S$, $a_N m_S$ and $m_N a_S$, represent $(\text{record} + a_N + a_S)$, $(\text{record} \times m_N \times m_S)$, $(\text{record} \times m_S + a_N)$ and $(\text{record} \times m_N + a_S)$, respectively. In the abbreviations, letter a and m represent additive and multiplicative adjustment factors, subscript N and S represent lactation number and stage.

variation of udder support among the traits was largest in Table 2, and therefore, greater estimates were obtained in both additive and multiplicative adjustment factors. On the other hand, adjustment factors of front teat placement were least changed over lactations. For lactation stage, adjustment factors were various according to physiological characters of linear traits. For instance, udder depth was changed according to lactation curve, while least changes were shown in

leg set.

For verification of adjustment factors, 20 sub-data sets were randomly sampled from Holstein data of 4,011,811 records as mentioned previously. Average size and standard deviation of sub-data sets were 200,604.2 and 378.2 in number of records, in which each sub-data consisted of approximately 5% of the original data. The analyses with the previous model used for ANOVA were carried out to investigate the impact on the variation of sub-data sets

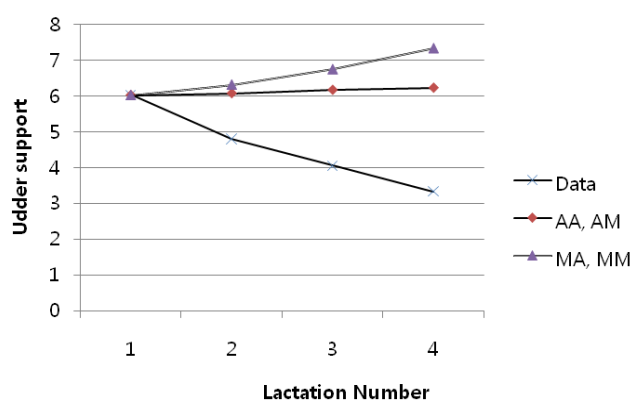


Fig. 1. Means of udder support and adjusted records by $a_N a_S$ (AA), $m_N m_S$ (MM), $a_N m_S$ (AM) and $m_N a_S$ (MM) according to lactation number.

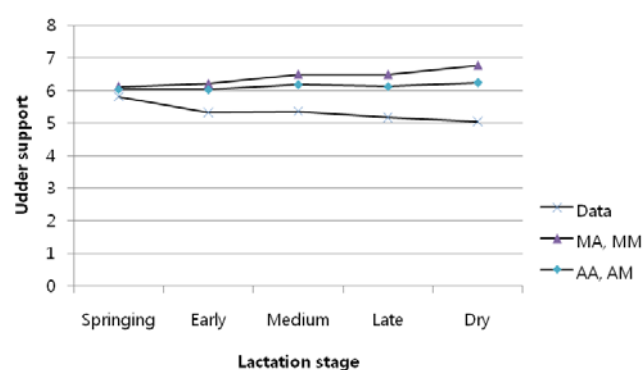


Fig. 2. Means of udder support and adjusted records by $a_N a_S$ (AA), $m_N m_S$ (MM), $a_N m_S$ (AM) and $m_N a_S$ (MM) according to lactation stage.

according to combinations of applied methods. Mean squares of linear traits were compared in Table 6. Average and standard deviation for mean squares of lactation number and stage from 20 sub-data sets were presented. No adjustment of data resulted in greater mean squares than any combination of adjustment methods applied for lactation and stage in all traits as shown in Tables 2 and 6. Additive adjustment (a_{NAS} : record + a_N + a_S) reduced more variation for lactation number of nearly all linear traits than multiplicative adjustments (m_{NMS} : record $\times m_N \times m_S$). For udder support, mean square of lactation number reduced greatly 2,320.7 to 5.1, comparing m_{NMS} with a_{NAS} . Further, any combination of multiplicative adjustment factor of lactation number in udder support with either additive (m_{NAS}) or multiplicative (m_{NMS}) adjustment factors of lactation stage caused great amount of mean square of lactation number in udder support. In addition, records of udder support were over-adjusted by combination of multiplicative adjustment factors, as shown in Figures 1 and 2. The small increments in mean square of lactation number, however, were observed in the traits of stature and body depth with m_{NAS} and m_{NMS} . The results indicate that adjustment of lactation number with the multiplicative factors were not efficient, comparing with additive adjustment factors. Combinations of a_{NAS} or a_{NMS} resulted in less variation for lactation number in most of linear traits. Under the circumstance, applications of a_{NAS} or a_{NMS} could be alternative. It was conclusive that additive adjustment was more appropriate for lactation number. As long as additive adjustment was adopted for lactation number, adjustment of stage was fitted well with either additive or multiplicative factors for all traits. For practical use, choice of the approaches was additive adjustment factor for both lactation number and stage (denoted by a_{NAS}), which can be easily implemented for classifier of AI studs to assess cows at herds.

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REFERENCES

- Cruikshank, J., Weigel, K. A., Dentine, M. R. and Kirkpatrick, B. W. 2002. Indirect Prediction of Herd Life in Guernsey Dairy Cattle. *J. Dairy Sci.* 85:1307-1313.
- Holstein Association USA. 2009. Breed Age Average Percentages (BAA%) for Holstein Cows. <http://www.holsteinusa.com>
- Khan, M. S. and Shook, G. E. 1996. Effects of Age on Milk Yield: Time Trends and Method of Adjustment. *J. Dairy Sci.* 79:1057-1064.
- Landete-Castillejos, T. and Gallego, L. 2000. Technical note: The ability of mathematical models to describe the shape of lactation curves. *J. Anim. Sci.* 78:3010-3013.
- Miller, R. H., Kuhn, M. T., Norman, H. D. and Wright, J. R. 2008. Death Losses for Lactating Cows in Herds Enrolled in Dairy Herd Improvement Test Plans. *J. Dairy Sci.* 91:3710-3715
- Moeller, S. J., Christian, L. L. and Goodwin, R. N. 1998. Development of adjustment factors for backfat and loin muscle area from serial real-time ultrasonic measurements on purebred lines of swine. *J. Anim. Sci.* 198. 76:2008-2016.
- Norman, H. D. and Cassell, B. G. 1978. Effect of Herd, Year, Age, and Stage of Lactation on Jersey Type Classifications. *J. Dairy Sci.* 61:352-360.
- Norman, H. D., Powell, R. L., Wright, J. R. and Pearson, R. E. 1996. Phenotypic relationship of Yield and Type Scores from First Lactation with Herd Life and Profitability. *J. Dairy Sci.* 79:689-701.
- Royal, M. D., Pryce, J. E., Woolliams, J. A. and Flint, A. P. F. 2002. The genetic relationship between commencement of luteal activity and calving interval, body condition score, production, and linear type traits in Holstein-Friesian dairy cattle. *J. Dairy Sci.* 85:3071-3080.
- Song, C. E., Sang, B. C. and Do, C. H. 2002. The development of adjustments for linear classifications in the Korean Holstein dairy cattle. *J. Anim. Sci. Technol. (Kor)* 44:1-12.
- Vanraden, P. M., Jensen, E. L., Lawlor, T. J. and Funk, D. A. 1990. Prediction of Transmitting Abilities for Holstein Type Traits. *J. Dairy Sci.* 73:191-197.
- Wiggans, G. R. and Dickinson, F. N. 1985. Standardization of NCDHIP dairy cattle lactation records. Fact Sheet G-2, ARSUSDA, Washington, DC.

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