Phenotypic Factor Analysis for Linear Type Traits in Beijing Holstein Cows**

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ABSTRACT : Factor analysis was applied to the phenotypic correlation matrix of 15 linear type traits (scored linearly 1 to 50 points) for 2035 Holstein cows of 38 sires computed from data collected between 1988 and 1992 in Beijing Shuangqiao Farm and Beijing Xijiao Farm. The 15 linear type traits were stature, body strength, body depth, dairy form, rump angle, rump length, rump width, rear leg side view, foot angle, fore udder attachment, rear udder height, rear udder width, udder cleft, udder depth and teat placement rear view. The first four components accounted for 49.1% of the total variance in type scores. Factor 1 reflected strong cows, with deep bodies, with long and wide rumps, and tall in stature. Factor 2 reflected cows with well attached fore udders, wide rear udders and whose udders were supported by strong suspensory ligaments with close teat placement. Factor 3 reflected cows with good dairyness, sickled in the hocks, high rear udders and udder floors above the hocks. Factor 4 reflected cows with sloping rumps from hooks to pins and with steep foot angle. Principal component and factor analyses are useful to clarify the relationships among type traits. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 11 : 1527-1530)***

Key Words : Holstein Cows, Type Traits, Factor Analysis

INTRODUCTION

The economic and genetic importance of type in dairy cows had created a need for a well-organized scoring system. The United States (US) National Association of Animal Breeders developed a classification program to measure individual traits from one biological extreme to the other (Thompson et al., 1980). This system of measurement was applied uniformly for all traits on a scale of 1 to 50 points (Thompson et al., 1983). Linear appraisal programs have been adopted by all US dairy cattle breed associations and nearly all artificial insemination organizations since 1983. Subsequently, this system was adopted by Japan, The Netherlands, Canada, Australia, Belgium, Denmark, Germany, Hungary, Israel, Italy, Great Britain, Spain and Sweden. Linear appraisal programs were introduced to China by Professor Shi Shoukun in 1986. Some relevant units in China had applied this system to evaluate dairy cattle and had achieved good results.

Many dairy conformation systems have evolved over time, and involve highly correlated traits which needed to be simplified. Large genetic correlations were found among udder traits. Thompson et al. (1983), Lawstuen et al. (1987), Foster et al. (1988), Klei et al. (1988), Norman et al. (1988) and VanRaden et al. (1990) found high genetic correlations between rear udder height and rear udder width, ranging from 0.85 to 0.95. Klei et al. (1988) found a high genetic correlation between udder depth and fore udder attachment (r_g=0.86). Diers et al. (1990) found a high genetic correlation between udder depth and fore udder attachment (r_g=0.92). Large genetic correlations were also found among non udder traits, for example, Lawstuen et al. (1987), Klei et al. (1988), VanRaden et al. (1990) and Misztal et al. (1992) found high genetic correlations between body depth and strength, ranging from 0.85 to 0.93. Multi-trait analysis and genetic evaluation of type traits also require that traits with similar biological significance and high correlations be grouped together or simplified. The objective of this study was to investigate the potential of principal component and factor analyses to clarify the relationships among linear type traits in Beijing Holstein cows.

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MATERIALS AND METHODS

Data

Data on 15 linear type traits for 2035 Holstein cows of 38 sires were collected between 1988 and 1992 in Beijing Shuangqiao Farm and Beijing Xijiao Farm. Fifteen linear type traits were scored from 1 to 50 where 1 and 50 were applied to the biological extremes of the traits: 7 traits (stature, body strength, body depth, dairy form, rump angle, rump length, rump width) broadly described the body characteristics of the cows, 6 traits (fore udder attachment, rear udder height, rear udder width, udder cleft, udder depth, teat placement rear view) described the udder, and 2 traits (rear leg side view and foot angle) described the feet and legs. The traits evaluated and a description of the ranges associated with each trait are presented in Table 1 (Thompson et al., 1983).

Table 1. Description of linear type traits in Holsteins

Traits	Score=1	Score=50
Stature	Small	Tall
Body strength	Narrow and frail	Wide and strong
Body depth	Shallow	Deep
Dairy form	Undesirable	Outstanding
Rump angle	High pins	Low pins
Rump length	Short	Long
Rump width	Narrow	Wide
Rear leg side view	Posty	Sickle hocked
Foot angle	Low	Steep
Fore udder attachment	Loose	Strong
Rear udder height	Low	High
Rear udder width	Narrow	Wide
Udder cleft	Flat	Deep
Udder depth	Below hocks	Above hocks
Teat placement rear view	Wide	Close

Methods

Principal components of factor analysis were computed using the phenotypic correlation matrix of 15 linear type traits in Beijing Holstein cows. Use of the correlation matrix ensured that type traits were weighted equally in the principal component analysis. Only those components whose eigenvalues were greater than 1.00 were retained. Eigenvalues greater than 1.00 represent the minimum number of factors which explain relationships among the type trait data. After the decision was made on how many principal components to extract and retain from the original set of variables, factor analysis with the varimax rotation as described by Kaiser (1958) was carried out to obtain factors such that each factor had only the minimum number of traits with large absolute values of loadings, scaled by multipling them by one hundred. The process was implemented with the Statistical Package for the Social Sciences (SPSS, 2nd ed.) software.

RESULTS

Mean and standard deviation of linear type traits in Beijing Holstein cows

The mean and standard deviation of linear type traits in Beijing Holstein cows and American Holstein cows are presented in Table 2.

From Table 2 it could be seen that: (i) Means of the 15 linear type traits in Beijing Holstein cows ranged from 15.8 (stature) to 31.8 (body depth) with from 3.9 to 9.1 SD. (ii) As compared to American Holstein cows, Beijing Holstein cows had smaller stature, lower and narrower rear udders, wider teat placement and the sloping rumps from hooks to pins. (iii) As compared to American Holstein cows, the type traits which described the body characteristics of Beijing Holstein cows had smaller standard deviations, while the udder traits had bigger standard deviations, indicating it was possible to improve the udder traits of Beijing Holstein cows by selection.

Table 2. Mean and standard deviation (SD) of linear type traits in Beijing Holstein cows and American Holstein cows

Traits	Mean±SD			
	This study	a	b	c
Stature	15.8±8.2	27.3±5.34	31.6±7.2	32.2±8.5
Body strength	31.3±6.2	25.1±6.42	29.8±6.5	30.0±7.6
Body depth	31.8±5.9	29.3±6.11	31.7±6.4	32.0±7.7
Dairy form	29.4±5.1	30.0±6.36	28.8±6.8	30.6±7.5
Rump angle	29.2±6.2	27.0±6.24	24.8±5.0	25.1±5.1
Rump length	22.6±5.8			
Rump width	27.7±7.0	26.8±5.99		
Rear leg side view	26.8±5.7	26.8±6.11	28.5±6.3	27.2±6.7
Foot angle	26.3±5.3	26.0±6.68	23.6±6.0	24.5±6.3
Fore udder attachment	27.5±8.2	27.9±6.96	25.4±6.5	25.5±7.2
Rear udder height	24.3±5.1	28.2±5.81	24.1±6.7	27.3±7.4
Rear udder width	21.2±3.9	27.9±6.64	23.6±6.6	27.2±7.3
Udder cleft	28.4±8.3	30.9±6.03	28.9±5.6	27.2±5.6
Udder depth	27.7±9.1	31.8±5.42	24.9±4.5	24.0±4.6
Teat placement rear view	24.5±7.4	27.8±7.45	26.7±5.8	24.8±6.1

a: Foster et al. (1988) American Holstein cows.
b: VanRaden et al. (1990) American Holstein cows.
c: Misztal et al. (1992) American Holstein cows.

Phenotypic factor analysis for linear type traits in Beijing Holstein cows

The eigenvalues and the proportion of total variance explained by principal components of phenotypic values of type traits are presented in Table 3, indicate that the first four principal components have eigenvalues greater than one. Four principal components were retained for the analysis and these accounted for 49.1% of the total variance in all type traits.

The factor pattern coefficients for four phenotypic factors of linear type traits in Beijing Holstein cows are shown in Table 4. The primary interest lies in the algebraic sign and magnitude of the coefficients and in the percentage of the total variation explained by a factor. A trait with a large coefficient contributes more to the factor than a trait with a small one. Once coefficients are determined, one should try to make physical or biological interpretations of the factors.

The method used to determine the value of a factor (also called a factor score) is suggestive of how the factor may be interpreted. A factor score is calculated by multiplying the standardized value of a trait with the trait's factor pattern coefficient and adding these products. The standardized value of a trait is calculated by subtracting its mean and

Table 3. Eigenvalues and proportion of total variance explained by principal components of phenotypic values of type traits in Beijing Holstein cows

Principal components	Eigenvalues	Proportion of total variance, %	Cumulative proportion of total variance, %
1	3.1553	21.0	21.0
2	1.7944	12.0	33.0
3	1.3291	8.9	41.9
4	1.0846	7.2	49.1
5	0.9998	6.7	55.8
6	0.9561	6.4	62.2
7	0.9178	6.1	68.3
8	0.8669	5.8	74.1
9	0.8245	5.5	79.6
10	0.7422	4.9	84.5
11	0.6296	4.2	88.7
12	0.5886	3.9	92.6
13	0.5415	3.6	96.2
14	0.4008	2.7	98.9
15	0.1688	1.1	100.0

dividing by its standard deviation. Thus, the factors can be interpreted and described according to the largest values (>35) of the coefficients of the traits (Table 4) because the traits having the largest coefficients contribute the most to the factor's score.

For factor 1, these traits are stature, strength of body, body depth, rump width and rump length. These five single traits contribute the most to the score for factor 1, and an animal with a large score for this factor would be a big, strong cow with wide and long rumps and tall in stature. The first factor accounts for 21.0% of the total variation in the type traits.

In practice, factors are often modified to simplify their interpretation. For example, traits with small coefficients (<35) were not included in the calculation for the score of factor one. This was done because the contributions of these traits to the factor score were relatively small and because the factor, based on the remaining five traits, was easy to interpret. The other three factors were modified in the same way with a trait being omitted when its coefficient was less than 35. In addition, some traits with coefficients larger than 35 were omitted from some factors. Udder cleft, udder depth and teat placement rear view were excluded from factor 1 so that the interpretation of this factor would involve only measures of general appearance. Similarly, rear udder width was omitted from factor 4 because it was already a part of factor 2, and its omission made the factor easier to interpret. Note that factors 2 and 3 are all related to the mammary system and represent 20.9% of the total variance. A complete description of each of the four factors is presented in Table 5.

Table 4. Factor pattern coefficients for four phenotypic factors of linear type traits in Beijing Holstein cows

Traits	Factors			
	1	2	3	4
Stature	46*	15	50*	-4
Body strength	75*	40*	-5	18
Body depth	74*	31	2	23
Dairy form	4	-5	53*	-40*
Rump angle	13	-33	0	38*
Rump length	60*	-2	32	1
Rump width	70*	28	2	-7
Rear leg side view	24	-34	42*	-24
Foot angle	-9	37*	-2	44*
Fore udder attachment	-25	62*	-7	-7
Rear udder height	-23	-2	50*	44*
Rear udder width	24	42*	-21	-43*
Udder cleft	-46*	45*	25	14
Udder depth	-57*	25	38*	3
Teat placement rear view	-44*	49*	11	-18
% total variance	21.0	12.0	8.9	7.2

Coefficients are multiplied by 100 and rounded; absolute values >35 have been flagged by an asterisk.

DISCUSSION

Factor analysis is a general method for analyzing data and is used to investigate the relationships among variables without designating some as independent and others as dependent. The purpose of a common factor analysis is to explain the correlations or covariances among a set of variables in terms of a limited number of latent variables. It is a procedure for removing the redundancy from correlated variables and presenting the variables with a smaller set of "derived" variables, called "factors". Therefore, factor analysis can be understood as a data-reduction technique by removing duplicated information from among a set of correlated variables. In recent years, the most frequently used factor analysis procedure in the literature has been the matrix transformation step, the extraction of all factors by the principal-factor method with eigenvalues of 1.0 or greater (eigenvalue-one criterion), and the rotation of these factors by varimax. The purpose of the rotation was to redistribute the variance of the related factors so that they are easier to interpret. The total procedure is relatively easy to use because it is an option of many computer statistical

Table 5. Descriptions of factors with largest factor values in Beijing cows

Factors	Description
1	Strong cows, with deep bodies, with long and wide rumps and tall in stature
2	Cows with well attached fore udders, wide rear udders, whose udders were supported by strong suspensory ligaments with close teat placement
3	Cows with good dairyness, sickled in the hocks, high rear udders and udder floors above the hocks
4	Cows with sloping rumps from hooks to pins and with steep foot angle

program packages, e.g., SAS (Statistical Analysis System) and SPSS.

Phenotypic factor analysis in this study extracted four principal components which accounted for 49.1% of the total variance in type scores. A phenotypic factor analysis for 18 linear type traits in the US Holstein cows was conducted by Sieber et al. (1987) who found that the first eight components accounted for 69.1% of the total variance in type scores.

Factor analysis can also be implemented on genetic values to obtain factors free from non-genetic deviations. Genetic factor analysis for 18 linear type traits of US Holstein cows was conducted by Sieber et al. (1988) who found that the first seven components accounted for 79.3% of the total variance in type scores. Factor analysis of genetic evaluations for 18 type traits of Canadian Holstein cows was conducted by Ali et al. (1998) who found that the first five components accounted for 70.2% of the total variance in type scores.

The discrepancy between the Sieber et al. (1987) study and this study might be due to the following reasons: 1) Different source of data, since Seiber et al. (1987) used first lactation data from the Twenty-First Century Genetics Mating Appraisal for Profit Program in the USA, 2) Different type traits, since traits in the Sieber et al. (1987) study were basic form, body strength, dairyness, stature, body depth, rump (side view), rear legs side view, foot angle, fore udder attachment, udder depth, rump width, rear legs rear view, rear udder height, rear udder width, suspensory ligament, fore and rear teat placement, disposition and milkout.

If the analysis was conducted with a genetic correlation matrix instead of a phenotypic correlation matrix, the result would be improved (Sieber et al., 1988). The advantage of a genetic correlation matrix would be that the set of derived factors would be free of environmental effects, and, therefore, the genetic composition of a factor could be seen more clearly. Also, inferences could be made on a genetic basis, which is useful in animal breeding.

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