Genetic Analysis of the Caliber Index in Lipizzan Horses Using Random Regression

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Abstract

The variability of the caliber index in Lipizzan horses was studied. The caliber index was defined as (heart girth / height at withers)*(cannon bone circumference / height at withers)*1000. The analysis included measurements (taken at 6, 12, 24 and 36 months of age) of 679 horses born between 1931 and 1999. The corresponding pedigree file consisted of 4786 horses. Covariance functions for the caliber index were estimated using a random regression model. Sex, age of dam and stud-year-season interaction were defined as fixed effects while direct additive genetic and permanent environment were defined as random effects. Polynomial functions of order four were adequate to explain additive genetic functions. The average caliber index increased from 119.1 to 135.4 at 6 to 36 months of age. The estimated heritabilities ranged from 0.16 to 0.20. Genetic correlations and permanent environment between consecutive measurements ranged from 0.28 to 0.77, and 0.78 to 0.99, respectively. The estimated covariance functions demonstrated heterogeneity of covariances and proved to be an adequate tool in estimating genetic parameters and trends of caliber index in Lipizzan horses.

Introduction

Lipizzan horse breed is one of the oldest cultural breed in Europe. Its beginning reaches back to year 1580 when the breed was established by the Habsburg Archduke Charles II with intention of providing nobility and royal prestige in the equestrian arts. Over the Centuries, the main breeding population of the Lipizzan horse has been situated over several State-owned studs in several countries that were once part of Austro-Hungarian Empire, today in Austria, Croatia, Hungary, Italy, Romania, Slovakia and Slovenia. The breeding of the Lipizzan horses in Croatia has long tradition dating from the XVIII Century (Steinhausz, 1943). Although, the breeding of Lipizzan horses have started on several large private studs (Cabuna, Stančić, Terezovac, etc...), for more then 100 years the stud from Đakovo is a central point of the Lipizzan horse breeding in Croatia.
    The three traditionally recorded basic measures describing morphological appearance of a horse are height at withers, heart girth and cannon bone circumference. These measurements

make possible to calculate the caliber index [(heart girth / height at withers)*(cannon bone circumference / height at withers)*1000] as a measure describing the volume and boniness of horses. The high values of the caliber index are characteristic for cold blood type of horses which are able to carry heavy loads for a long time. On the contrary, the low values of the caliber index are characteristic for warm blood type of horses which are able to run fast and long distances. For example, Posavina horse has the caliber index values that are around 200, while thoroughbred horses has caliber index values around 140 (Druml and Sölkner, submitted). Potential selection for a Caliber Index would imply changes in a type of horse within a breed.

The objective of this study was to estimate (co)variance components, heritabilities and correlations of the caliber index in Lipizzan horses in Croatia. The changes in means and variability from six to 36 months of age and during the breeding period from years 1940 to 2000 were analyzed.

Material and Methods

Data consisted of repeated measurements of 679 Lipizzan horses, born between 1931 and 1999 at a stud in Đakovo, Croatia. Measurements were taken at 6, 12, 24 and 36 month of age. Pedigree records were available since the year 1740. By including pedigree there was a total of 4789 horses included in the analyses.

The caliber index was defined as:

$$\left(\frac{\text{heart girth}}{\text{height at withers}}\right) * \left(\frac{\text{cannon bone circumference}}{\text{height at withers}}\right) * 1000$$

This is a measure describing the volume and boniness of the horse.

Table 1. Descriptive statistics of caliber index in Lipizzan horses

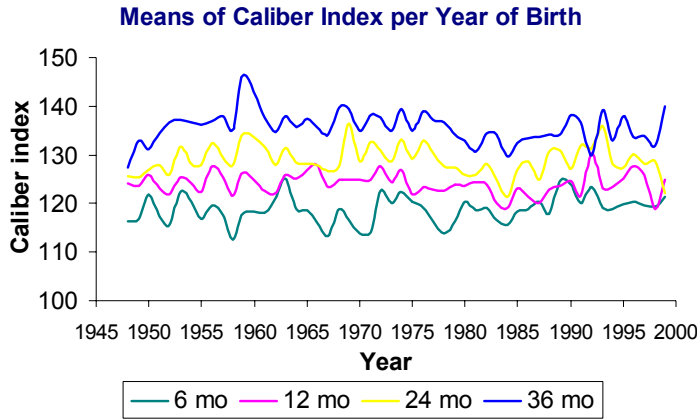| Age	No. of horses	Mean	St. dev.	Coefficient of variation (%)
6	668	119.1	5.7	4.7
12	676	124.0	5.7	4.6
24	665	128.9	6.2	4.8
36	618	135.4	5.7	4.2

Figure 1. *Changes in means of caliber index from year 1948 to 2000*

Covariance functions were estimated by using random coefficient regression model. Sex, age of dam, stud x year x season and age of horse were defined as fixed effect. Additive genetic effect and environmental variance between horses were defined as random effects. The cubic and quadratic regression was shown to be appropriate in explaining additive and environmental variance between horses, respectively. Legendre polynomials were used in estimating covariance functions (Kirkpatrick et al., 1990). The covariance matrix of regression coefficients were used to estimate covariances for values in different ages. For example, for additive genetic covariances (**G**):

$$\mathbf{G} = \mathbf{\Phi H \Phi'}$$

where **H** is a matrix of covariances of additive genetic regression coefficients, and **Φ** is a matrix of Legendre polynomials. Similarly, the covariance matrix of permanent environment effect was obtained.

Data were edited and prepared for the analyses using SAS (SAS Institute, 1999-2001). Parameters of multiple trait model and random regression were estimated using a set of programs written by Karen Meyer (Meyer, 1998) and the program VCE 5.1 (Kovac and Groeneveld, 2003).

Results and discussion

The average caliber index increased from 119.1 to 135 at the 6 to 36 months of age. Druml and Sölkner (submitted) showed that caliber index of mature Lipizzan horses is 154 and 156 for mares and stallions, respectively. Thus, with respect to caliber index there is still large difference between three years old and mature Lipizzan horses.

The estimated phenotypic, additive genetic and environmental variances between horses at different growth stages (from 6 to 36 months) are shown in figure 2, and the corresponding estimates for heritability and repeatability are presented in figure 3. The estimated heritabilities ranged from 0.16 for six months old horses to 0.20 for 36 months old horses. For the mature Noriker horse, Druml and Sölkner (submitted) estimated heritability of 0.36 with standard error 0.03 which is somewhat higher then estimates obtained in our study.
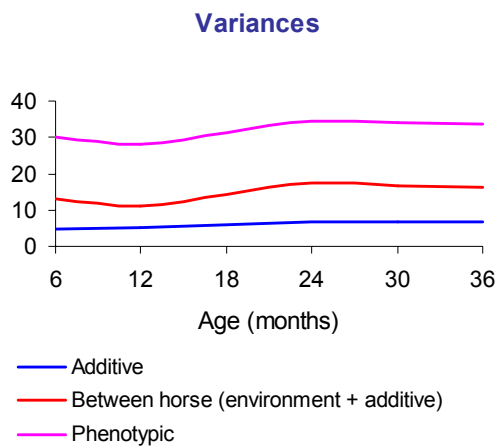
Variances

Figure 2. Phenotypic, additive genetic, and environmental variance between horses for caliber index at different growth stages (from six to 36 months).
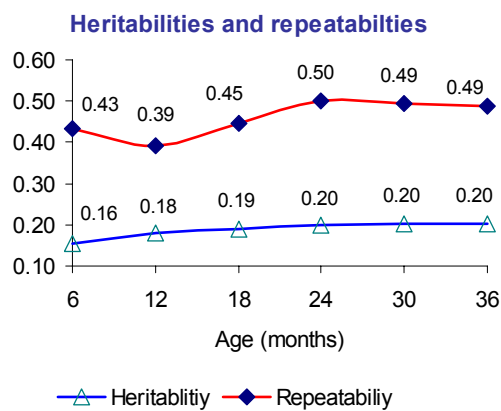
Heritabilities and repeatabilties

Figure 3. Estimates of heritability and repeatability for caliber index at different growth stages (from six to 36 months).

Covariances between 24 and other Ages
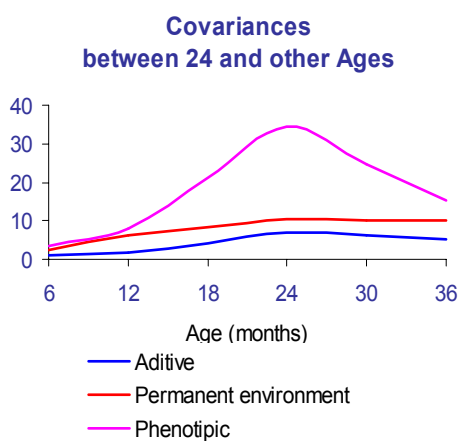

Figure 4. Covariances between caliber index at 24 mo of age and all other ages

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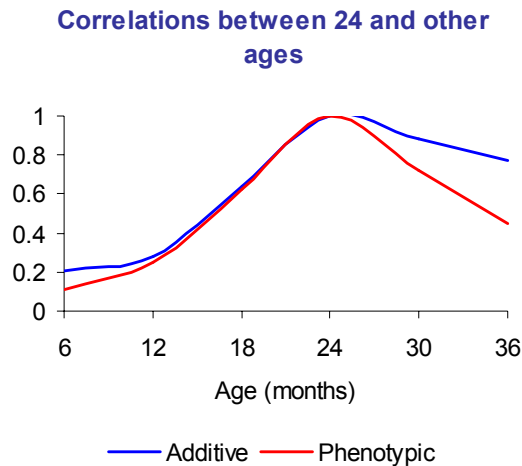**Correlations between 24 and other ages**

Figure 5. Correlations between caliber index at 24 mo of age and all other ages

Genetic correlations between caliber indexes at 24 months of age and all other ages showed that genetic correlations decreased as measurements are more distant in ages (figure 5). The phenotypic correlations are slightly lower then genetic correlations. Overall, the results in figure 4 and 5 show that, it is difficult to predict caliber index of mature horses on a basis of measurements taken at young stages.

The solution for animal effects from animal models can be used to predict breeding values at any age. Changes in average breeding values throughout the years (genetic trend) for the caliber index measured in different age stages are shown in figure 6. Note relatively larger fluctuation in period between years 1970 and 1998 and again after 1990. This was the result from intentional selection and combined effects of genetic drift rising from the small effective population size and migration from Lipizzan studs from other breeding populations which were different with respect to heart girth, height at withers, and cannon bone circumference (Zechner et al. 2001.). For a genetic structure of the Lipizzan horse see Achmann et al. 2004.
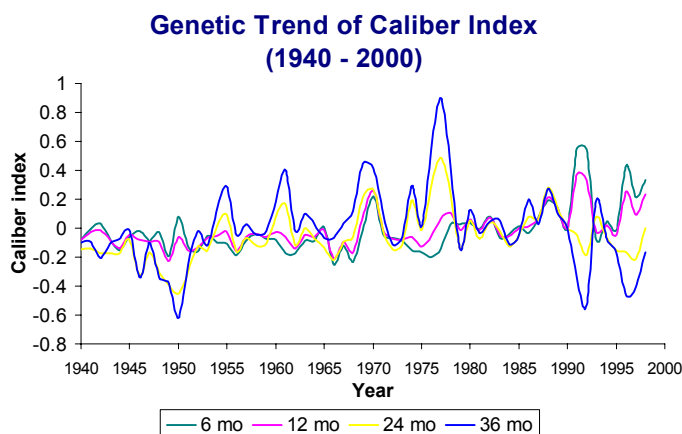

Figure 6. Genetic trend for caliber index in Lipizzan horse across different growth stages (6, 12, 24 and 36 month old) and time (1940–2000)

Conclusions

The estimated heritabilities ranged from 0.16 to 0.20. The estimates of genetic and phenotypic correlations between consecutive measurements ranged from 0.28 to 0.77, and 0.25 to 0.45, respectively. Polynomial functions of order four and three were adequate to explain additive genetic and permanent environment covariance functions, respectively. Estimated covariance functions from this study demonstrated heterogeneity of the caliber index variances and covariances in Lipizzan horses. Low genetic correlations between young horses and old horses show that it is difficult to select horses for a caliber index based on measurements taken in young animals.

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