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Genetic Analysis of the Withers Growth In Lipizzan Horse Using Random Regression

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Abstract

Longitudinal records of the withers height (taken at birth, six, 12, 24 and 36 months of age) were analyzed for 879 Lipizzan horses born in Croatia between 1931 and 1999. The corresponding pedigree file consisted of 5010 horses. Covariance functions were estimated by using bivariate animal models with ages defined as separate traits and by using random regression model directly on data. In all models, sex, age of dam and interaction stud-year-season were considered as fixed effects while individual horses and residual errors were considered as random effects. The random regression model also included permanent environment effect due to repeated measurements. Polynomial functions of order three were adequate to explain additive genetic functions. Estimated heritabilities from bivariate and random regression models ranged from 0.14 to 0.25 and from 0.12 to 0.23, respectively. While genetic correlations between longitudinal records ranged from 0.76 to 0.99, corresponding phenotypic correlations ranged from 0.12 to 0.49. Overall, the estimated covariance functions from this study demonstrated heterogeneity of covariances of wither height in Lipizzaner horse and proved to be adequate in estimating covariances and correlations between heights at any two age points from birth to 36 months of age.

Introduction

Lipizzan horse breed is one of the oldest cultural breed in Europe. Its beginning reaches back to year 1580. As for any population one of the interests is to investigate changes in growth within individual horses, as well changes in growth curves through a wider period of time. Changes can be observed not only in means, but there can be heterogeneity in variances and covariances in different ages. The way how to investigate those changes in variances and covariances is by defining appropriate covariance functions (Kirkpatrick et al. 1990). Covariance functions should be continuous functions that should make possible to estimate covariance within animals (subjects) between measures at any two age points t_i and t_j, and variances between animals at any age point t_i.

Possible approach to estimate covariance functions is by using the multiple trait model. Here, measurements at different ages are considered as different traits and different variances and covariances are assumed between those 'traits' (Wolfinger, 1996). Common problems with this approach are that due to high correlations between 'traits' it is difficult to obtain convergence, and records must be taken at the same ages for all animals. The alternative is to use random coefficient regression model. Here, each horse has its own regression defined over age (Meyer, 1998b). Thus, the regression coefficients are assumed to be random variables and there is a covariance structure among regression coefficients. These can be used to estimate covariance functions, i.e. variances and covariances between values for different ages. The advantages of this approach are time points between measures need not be equal for each horse, the number of observations per horse can be different. Disadvantages may be that polynomials of higher order do not easily converge, and, often, fluctuations at the extremes of observed age interval appear.

Therefore, the objective of this study was to estimate covariance function, which will explain changes in variances and covariances of withers height of Lipizzan horses from birth to 36 months of age. Consequently, heritabilites for any age point and correlations between any two age points can be estimated. Also, genetic and phenotypic changes in wither heights from 1931 till today will be presented.

Material and Methods

Data consisted of repeated measurements of 879 Lipizzan horses born between 1931 and 1999 at a stud in Đakovo, Croatia. Measurements were taken at birth, six, 12, 24 and 36 month of age. Pedigree records were available since the year 1740. By including pedigree there was a total of 5010 horses included in the analyses. Descriptive statistics of wither height are shown in table 1. The changes can be seen not only in means but in standard deviations and coefficients of variation. This may imply heterogeneity of variance. Note decrease of variability as age increases. Similarly was observed by Saastamoinen (1990) in Finnhorse.

Table 1. Descriptive statistics of withers height (cm) in Lipizzan horses

Age	No. of horses	Mean (cm)	St. dev. (cm)	Coefficient of variation (%)
0	855	101.1	5.3	5.2
6	769	135.7	4.7	3.5
12	737	147.5	5.5	3.6
24	679	155.8	4.5	2.9
36	657	161.8	3.5	2.2

More informative is to see the changes in wither height (phenotype) in years (Figure 1.). The mean in particular year corresponds to horses born in that year. Note fluctuation in wither height throughout the years.

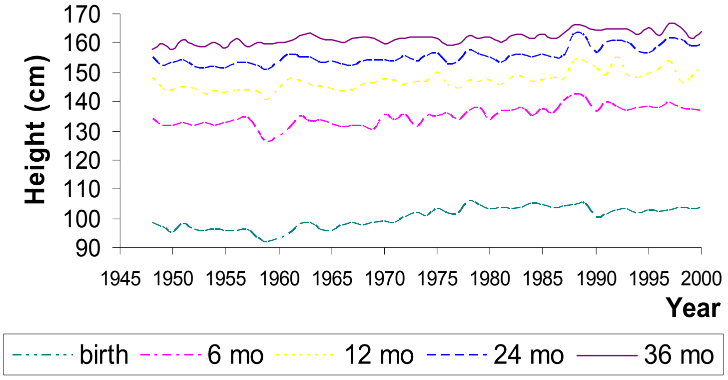

Figure 1. Changes in means of withers heights from year 1945 to 2000

Covariance functions were estimated by two approaches: a) by estimating variances and covariances from a set of two traits animal models, traits defined as measurements at different ages for each pair or age; b) by using random coefficient regression model.

Two traits animal models: Additive genetic (**G**) and phenotypic covariance matrix (**P**) among 'traits' were estimated by using a set of two trait animal models. The **G** and **R** covariance matrices for all ages together are obtained from pooled estimates from the two traits models. Sex, age of dam and stud x year x season were defined as fixed effect, and animal /additive genetic effects) and error (environmental) effect are defined as random. Covariance functions were then estimated using appropriate covariance matrices.

Random coefficient regression model: For each horse a regression over age was defined. Thus, the regression coefficients are assumed to be random variables. Further, regressions were split additive genetic effect regression and permanent environment regression due to a horse. Sex, age of dam, stud x year x season and age of horse were defined as fixed effect. The quadratic regression was shown to be appropriate and sufficient to explain changes in withers height. To estimate variances and covariances of regression coefficients, Legendre polynomials were used (Kirkpatrick et al, 1990). As the Legendre polynomials are defined over interval (-1,1), the ages were transformed to that interval. 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 for birth and age at six months were corrected prior to main analyses on maternal genetic and maternal nongenetic effects (if any) using univariate models for each age measurements.

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

Results and discussion

The differences in estimating phenotypic and additive genetic variance from a set of two traits models were observed (Figure 2). Note more variability in additive genetic variance.

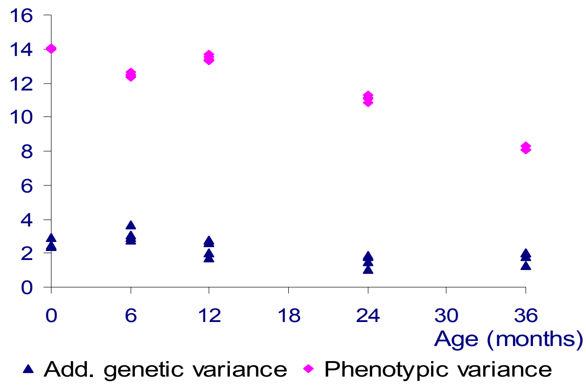

Figure 2. Illustration of estimated variances from a set of two traits animal models.

Comparison of estimated additive genetic and phenotypic variances from the covariance functions estimated with two trait models and random regression model is shown in Figure . Although there are slight differences in estimated variances, both approaches show decrease in variability as age increases. Similar decrease in variances was reported by Saastamoinen (1990).

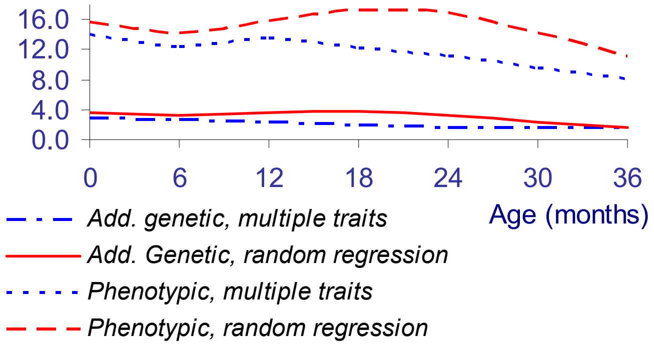

Figure 3. Additive genetic and phenotypic variances for withers height estimated by a set of two traits animal models and random coefficient regression model

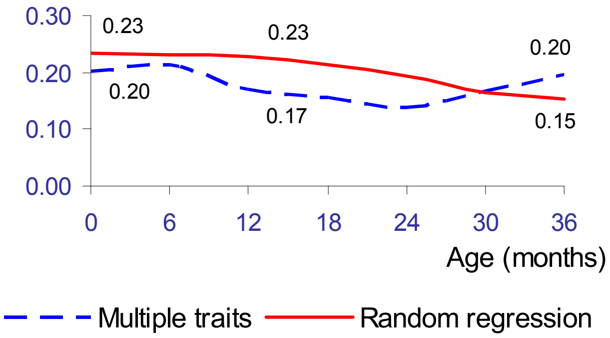

Figure 4. Heritabilities for withers height estimated by a set of two traits animal models and random coefficient regression model

Heritability estimates obtained ranged from 0.15 to 0.23 and were influenced by the approach (multivariate or random regression) used, mainly because differences in estimated phenotypic variances. In both cases, heritability estimates are in agreement with those obtained in Eriksson (1948), Varo (1965), von Butler (1986), von Butler & Krolikowsky (1986) and Zachner et al. (2000) but are much lower than high estimates (from 0.60 to 0.88) obtained in Hintz et al. (1978), Arnasson (1983) and Klemetsdal & Wallin (1986).

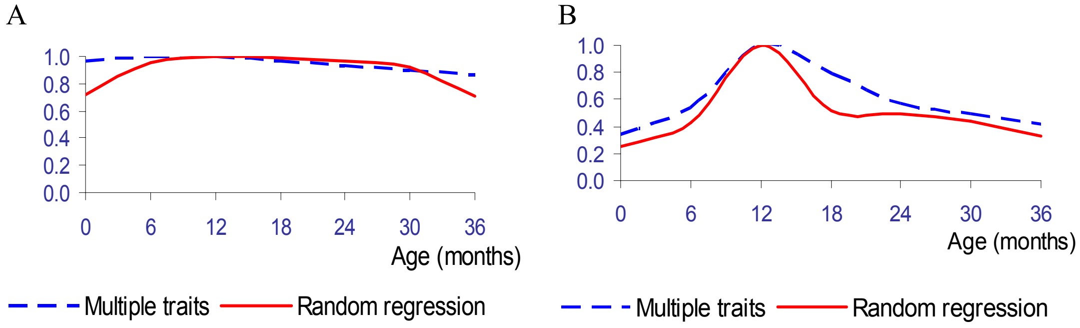

Figure 5. Additive genetic (A) and phenotypic (B) correlations between withers height at 12 mo of age and all other ages estimated by a set of two traits animal models and random coefficient regression model

Genetic correlations between withers height at 12 months of age and all other ages estimated by a set of two traits animal models and random coefficient regression model (Figure 5) shows that genetic correlations are close to 1, slightly decreasing for more distant ages. Greater differences were observed at birth and 30 months of age using random regression approach. This fluctuation at the extreme age is often observed in polynomial regression, especially for higher order polynomials.

The phenotypic correlations are much lower then genetic correlations. Again more distant are the ages, the phenotypic correlations decrease.

The solution for animal effects from animal models can be used to predict breeding values of horses for withers height at any age. Changes in average breeding values throughout the years (genetic trend) are shown in Figure 6. Note relatively larger fluctuation in period between years 1970 and 1990, which is result from intentional selection as well as drift coming from the small effective size of "Croatian" Lipizzan population.

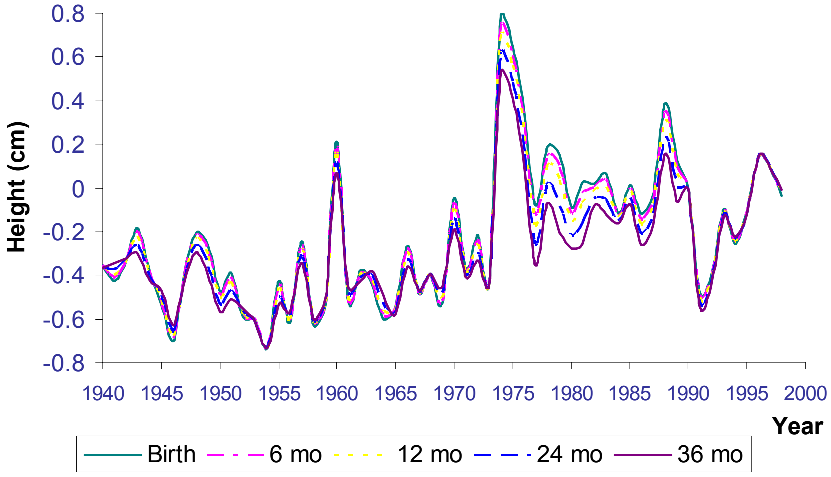

Figure 6. Genetic trend for withers height

Conclusions

Estimated heritabilities from two trait models ranged from 0.14 to 0.25, and those from random regression ranged from 0.12 to 0.23. Genetic correlations between ages ranged from 0.76 to 0.99 and phenotypic correlations ranged from 0.12 to 0.49. Estimated covariance functions from this study demonstrated heterogeneity of covariances of wither height in Lipizzan horse. Polynomial functions of order three were adequate to explain additive genetic covariance function.

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