Thesis of the Ph.D. dissertation

BREEDING VALUE ESTIMATION OF SPORTHORSES BASED ON THEIR SHOW JUMPING PERFORMANCE

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2015

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I. BACKGROUNDS AND OBJECTIVES OF THE DOCTORAL THESIS

Today there is a growing interest towards those scientific methods which develop the horse breeding through help to define the important characteristics in the breeding aim. One element of this process is the breeding value estimation, which will allow the preselection of animals, thus select the most suitable horses to become a breeding animal.

Direct and indirect selection methods can be distinguished in selection of sporthorses. Direct methods estimate the individual's performance, while the indirect ones measure some characteristics in correlation with the performance. Direct selection methods are generally based on performance achieved in some equestrian sports.

If we want to breed an animal we need to know the hereditary ability of the animal, the genetic value of the horse compared to the average value of the population. To express this genetic value, the breeding values must be estimated, but we should note this value is valid only in the examined population. It is therefore extremely important to estimate the breeding value of sporthorses in each equestrian discipline, or for each horse breed.

MIHÓK et al (2009) emphasize the need for research and results, because due to the lack of research and information it is more difficult to join to the European scientific life. The information that is produced in the world is very much needed, and should be expanded with the Hungarian results.

In Hungary in recent years POSTA et al (2007b) have been developed a breeding value estimation method as a result of many years of research. The results the estimated genetic parameters and breeding values could help the farmers and animal breeders to reach a successful breeding scheme through making more conscious the breeding and selection decisions.

Objectives

1. **Preparation of Hungarian show jumping results for the analysis**
    - To collect the show jumping data between 1996 and 2011, and merge them into one database.
    - To gather and build up the pedigree information of sporthorses.
    - To present some descriptive statistics which have effect on breeding values estimation.
2. **Analysis of the performance of show jumping horses**
    - To examine the performance using different measurement variables.
    - To compare the models of transformed measurement variables, and to chose the best model and best type of transformation.

3. **Genetic parameter estimation for traits based on show jumping performance**
    - To estimate genetic parameters for the best performance traits, using repeatability animal model.

4. **Evaluation of performance between different competition levels**
    - To estimate genetic and phenotypic correlation between performances achieved at different competition levels.

5. **Presentation of the estimated breeding values, evaluation the show jumping results with random regression models**
    - To estimate breeding values for sires using the best performance variable.
    - To find the best fit model for using random regression method.
    - To estimate genetic parameters with random regression models.

II. RESEARCH METHODS

Show jumping data between 1996 and 2011 were provided by the Association of Hungarian Equestrian Show Jumping in Microsoft Office Excel form. Data contained show jumping results of competitions which were held in Hungary, and results of some Hungarian riders who competed abroad as well. Microsoft Office Access 2000 software was used to prepare and filter the data before the analysis applying SQL language. Name, ID and gender of the horse, rider, date, location and category name of the competition, fault point and placing (rank) were included in the database. National Horse Breeding Information System (OLIR) supported us to collect the pedigree information of horses. In case of sporthorses that were not recorded in the national registration system, its pedigree could be identified from sport horse registries (before 2007 paper form, from 2007 electric form). Gathering pedigree information of foreign horses (do not have ID, came to Hungary only for taking place in some competition) was feasible through getting information from the Association of Hungarian Sporthorse Breeders.

Pedigree of horses was analysed by the Pedigree Viewer software also, to check the consistence of the data. Finally 40142 animals were included in the pedigree data four generations back.

Nearly 10 % of the records in the database (37,000 starts) were biased through missing or false information. Irreplaceable data (finally only 1% of the entire database) were ignored due to missing ID and missing pedigree information. After data screening and cleaning 10199 horses with 358342 records were prepared and ready for the analysis.

To measure the show jumping performance of the horses measurement variables were created based on ranks, number of starters and difficulty level. Information about winnings was not available; fault points and time were not recorded in all case. The performance measurement variables were transformed with elementary functions to make the error term of the models normal distribution because of the REML method. Repeatability animal model was fitted to these measurement variables as proposed by MRODE (1996). To define the model an analysis of effects is needed whether they have significant effect on the performance or not. The analysis of fixed and random effects included in the animal model was performed with SAS (SAS/STAT, 2003) software, using SAS GLM method. Different models were compared based on their coefficient of determination (R^2) and RMSE values.

Difficulty level of the competition was taken into account in two ways. Level of the competition was included in the animal model as fixed effect, these were the non-weighted models. While difficulty level was considered as a weighted factor in the weighted models, so performance scores were defined in a wider range of interval. Performance score was higher for a horse competing at higher level, standard deviation of data increased, and performance of horses could be distinguished in a better way.
The following repeatability animal model was used for the analysis.

Model for non weighted performance score:

$$Y_{ijklmno} = \mu + Age_i + Gender_j + Year_k + Location_l + Level_m + Rider_n + Perm_o + Animal_o + e_{ijklmno}$$

Model for weighted performance score, competition level was used as a weighting factor:

$$Y_{ijklno} = \mu + Age_i + Gender_j + Year_k + Location_l + Rider_n + Perm_o + Animal_o + e_{ijklno}$$

μ denotes the average value, fix effects were age and gender of the horse, year, location and level of the competition, random effects were rider, animal and permanent environmental effect, $e_{ijklmno}$, e_{ijklno} denote the error term.

Competitions were categorized into 5 groups based on their difficulty level by professionals. Types of used transformations in generalized form are presented in *Table 1*. The performance score was subtracted from a constant ‘c’, due to the strictly monotone trait of the square root and logarithmic functions. The constant ‘c’ value was determined in such a way that the result of the subtraction be non negative, as BUGISLAUS et al (2005) suggested. A better ranked horse got higher score in this way.

Table 1.: Transformed performance measurement variables based on ranks

Square root	Logarithmic	Inverse normal
$c-\sqrt{rank}$	$c-log_a(rank)$	$Y_j^i=\theta^{-1}\left(\frac{r_i-k}{N-2k+1}\right)$
$\left(c-\sqrt{rank}\right)*level$	$\left(c-log_a(rank)\right)*level$	$Y_j^i=\theta^{-1}\left(\frac{r_i-k}{N-2k+1}\right)*level$
$\left(c-\sqrt{rank}\right)*level^2$	$\left(c-log_a(rank)\right)*level^2$	$Y_j^i=\theta^{-1}\left(\frac{r_i-k}{N-2k+1}\right)*level^2$

In case of the inverse normal transformation

Y_j^i= performance score of j. horse competing at i. competition

r_i= reached placing at i. competition

N = number of observation (number of competitors at a given competition)

c, k = fixed constant

$\theta^{-1}(x)$= inverse function of the standard normal distribution function

Performance scores are based on ranks and number of competitions as well in case of inverse normal transformations. For the ‘k’ constant value BLOM (1958) suggested k=3/8, TUKEY (1962) k=1/3, and WAERDEN (1952) k=0.

Sport performance can be characterised by the number of first to third rank, and the ratio of first to third ranks as well. These kind of measures are grouped in *Table 2* classified by transformation types.

Table 2.: Transformed performance measurement variables based on first to third ranks and number of starts

Square root, third root	Logarithmic	Other
$\sqrt{ratio\ of\ 1.-3.\ ranks}$	$lg(number\ of\ 1.-3.ranks+1)$	number of 1.-3. ranks /year
$\sqrt{number\ of\ 1.-3.\ ranks}$	$\ln\left(\frac{X+0{,}5}{100{,}5-X}\right)$ X=ratio of 1.-3. ranks *100	$\left(\frac{number\ of\ 1.-3.ranks}{number\ of\ starts}\right)^{0{,}8}$
$\sqrt[3]{number\ of\ 1.-3.\ ranks}$	$lg(number\ of\ starts)$	$\left(\frac{number\ of\ 1.-3.ranks}{number\ of\ starts}*100\right)^{0{,}8}$
$\sqrt[3]{number\ of\ 1.-3.\ ranks/year}$		

Additive genetic variance, permanent environmental variance, rider variance and error variance were estimated by REML method, using VCE-6 software (GROENEVELD et al, 2010). Heritability and repeatability values were estimated from these variances.

Phenotypic and genotypic variances were estimated between the different competition levels, considered the performance at difficulty levels as different traits.
Breeding values estimation was executed using the BLUP method based on repeatability animal model with PEST software (GROENEVELD et al, 1990). The estimated breeding values were transformed to have an average value 100, and standard deviation 20 (KOENEN 2005):

$$T\acute{E}_{transzf} = 100 + \frac{T\acute{E}_o - \overline{T\acute{E}_o}}{\sigma_a} * 20$$

where

$T\acute{E}_{transzf}$ = transformed breeding value

$T\acute{E}_o$= estimated breeding value originally

$\overline{T\acute{E}_o}$= average of breeding values of the reference population

σ_a= square root of the additive genetic variance of the trait

Reliability value of each breeding value was estimated. Rank correlation analysis (SPEARMAN, 1904) was performed between the breeding values of the sires. Using this method the order of sires can be compared.
Those 4 to 11 years old horses were included in the random regression analysis that had at least 5 records. The filtered database contained 269598 records in total. Random regression model was fitted to the best 3 transformed performance score, the weighted Blom scores, weighted square root and weighted logarithmic performance scores. Horses were categorized into 6 age groups, between the age groups error variance was assumed to be constant.
For fitting random regression model Legendre polynomial was used

$$Y_{ijkl}\,(t) = \mu + Gender_i + Year_j + Location_k + Rider_l + \sum_{n=1}^{N} t^n + \sum_{n=1}^{N} \alpha_0 \theta_n\,(q(t)) + \sum_{n=1}^{N} \gamma_0 \theta_n(\,q(t)) + e_{ijkl}$$

where μ denotes the average value, fix effects were gender of the horse, year and location of the competition, rider was considered as random effect, t denotes the age in days, θ_n refers to the Legendre polynomial, α_0 stands for coefficients of additive genetic effect of the animal, γ_0 stands for coefficients of permanent environment effect, e_{ijkl} denotes the error term.

Variance components of the random regression coefficients were determined with REML method using VCE-6 software. Eigenfunctions and their eigenvalues were determined as well.

III. MAIN STATEMENTS OF THE THESIS

Some descriptive statistics affecting breeding values

Evaluating the 1996-2011 show jumping data we concluded that horses have short sport carrier and low number of records. This fact reduces the reliability of breeding values, hereby the substantiation of professional selection. Two thirds of the horses (67%) spend a maximum of three years in the sport, a horse start competing at young age cannot show its potential performance. One third of the horses competed in show jumping less than 1 year. The calculated average length of the carrier was 3.14 years, and is below compared to international data. Besides the short carrier the average number of starts per horse is low 31.59. 80% of the horses finished their carrier with less than 50 records. We recommend testing more sporthorse in show jumping to get a more balanced image of the horse's performance through increasing the number of starts per horses. The information we get is intended to the future results, helps to make the selection decision more conscious through selecting the best animals.

Evaluation of the variables used for performance measurement

Model for weighted performance measurement variables fitted better, had higher R^2 value, than the non-weighted models (*Table 3*.). Despite our conjecture using the square of difficulty level in the models did not result much more model than using the difficulty level as weighting factor. Considering the level weighted traits the square root and the inverse normal transformation resulted better fitting than the logarithmic transformation.

Table 3.: Comparing fitted models of traits based on show-jumping performance

Measurement variable	R^2	R	RMSE
$15-\sqrt{rank}$	0.18	0.42	1.30
$(15-\sqrt{rank})$*level	**0.47**	0.69	5.96
$(15-\sqrt{rank})$*level^2	**0.46**	0.68	26.71
10–$\log_2$(rank)	0.16	0.40	2.00
(10–$\log_2$(rank))*level	**0.43**	0.66	0.70
(10–$\log_2$(rank))*level^2	**0.45**	0.67	4.86
3–lg(rank)	0.16	0.40	2.19
(3–lg(rank))*level	**0.43**	0.60	2.19
(3–lg(rank)) *level^2	**0.45**	0.64	8.38
5.5–ln(rank)	0.16	0.40	1.31
(5.5–ln(rank))*level	**0.36**	0.66	3.89
(5.5–ln(rank)) *level^2	**0.41**	0.67	16.21
Blom scores+3	0.09	0.30	0.82
(Blom scores +3) * level	**0.45**	0.67	1.92
(Blom scores +3)*level^2	**0.46**	0.68	7.73
Tukey scores +3	0.09	0.30	0.83
(Tukey scores +3) * level	**0.45**	0.67	1.53
(Tukey scores +3)* level^2	**0.47**	0.69	7.61
Waerden scores +3	0.09	0.30	0.83
(Waerden scores +3) * level	**0.45**	0.67	1.52
(Waerden scores +3)* level^2	**0.47**	0.69	7.61

Estimation of genetic parameters

Significant and low 0.02-0.07 heritability values (h^2), significant and low and moderate 0.08-0.25 repeatability values (R) were estimated in case of all traits similar to literature (*Table 4.*). The reason could be the low number of progenies in sport, low number of starts per horse, and the presence of those non additive effects which affect the performance of the horse.

Table 4.: Heritability and repeatability values of the traits

Measurement variable	**h^2**	**R**	**Rider/V_P**	**Permanent environment/V_p**	**Error /V_p**
15-squareroot(rank)	0.02 $_{(0.003)}$	0.09	0.06$_{(0.003)}$	0.06$_{(0.003)}$	0.85$_{(0.003)}$
15-squareroot(rank)*level	0.07 $_{(0.006)}$	0.25	0.15$_{(0.004)}$	0.18$_{(0.006)}$	0.60$_{(0.004)}$
15-squareroot(rank)*level^2	0.06 $_{(0.006)}$	0.23	0.12$_{(0.004)}$	0.17$_{(0.006)}$	0.65$_{(0.004)}$
10-log2(rank)	0.02 $_{(0.003)}$	0.08	0.07$_{(0.003)}$	0.06$_{(0.003)}$	0.85$_{(0.003)}$
10-log2(rank)*level	0.07 $_{(0.006)}$	0.23	0.12$_{(0.003)}$	0.17$_{(0.006)}$	0.64$_{(0.004)}$
10-log2(rank)*level^2	0.05 $_{(0.006)}$	0.22	0.11$_{(0.003)}$	0.17$_{(0.005)}$	0.66$_{(0.004)}$
Blom score +3	0.05 $_{(0.005)}$	0.13	0.05$_{(0.002)}$	0.07$_{(0.004)}$	0.83$_{(0.003)}$
(Blom score+3) * level	0.07 $_{(0.006)}$	0.23	0.11$_{(0.003)}$	0.16$_{(0.006)}$	0.66$_{(0.004)}$
(Blom score+3) * level^2	0.05 $_{(0.005)}$	0.22	0.11$_{(0.003)}$	0.17$_{(0.005)}$	0.67$_{(0.004)}$

V_p denotes the phenotypic variance

Higher heritability and repeatability values were estimated in case of the weighted models, values were more than twice higher compared to the non weighted models. The use of competition level as a weighting factor resulted not only a better model, but increased the heritability and repeatability values as well. As a conclusion we can say that it is worth to consider the competition level as a weighting factor in the model, instead of considering it as a fixed effect in the model.

In case of the weighted models rider and permanent environmental effect was greater on performance of horses, because they explained higher proportion of the phenotypic variance. The error term was the major part 60-85% of the phenotypic variance, it includes all effects what we could not define and take into account in the model.

For further analysis we recommend the following transformation types to measure the performance:

- (15-square root (rank))* level
- (10-log2(rank))*level
- (Blom score + 3) * level

Evaluation of performance at different competition level

Moderate and high (r_g = 0.48 to 1.00) genetic correlations were estimated between performance on the first four groups using the logarithmic and square root transformations. In these cases the genetic correlation values were significant ($P < 0.05$)

between the first 3 competition levels. In case of the Blom method strong and significant ($P < 0.05$) genetic correlation values were calculated between the first 4 levels. Due to the low number of records in the 5. competition level, the result could not be compared with other levels. The close correlation values suggest that horses are able to reserve their position at higher level which rank was reached at lower level.

The phenotypic correlations for all three measures showed loose (r_f = 0.07 - 0.22) values between performance reached at different competition level. As the distance was higher between the difficulty levels, the phenotypic correlation decreased.

Estimated breeding value of sires

Strong Spearman correlation values were calculated between the breeding values estimated with the 3 different transformation method (r = 0,97 - 0,99), so order of the sires could be considered as almost same. From the 2350 sires we could estimate reliable breeding value (at least 0.7 reliability value) in case of 35 sires. The minimum progeny number was 27. Analysis resulted breeding values with one standard deviation unit above the average (at least 120 breeding value) in case of 12 sires. From these 7 Holsteiner sporthorse, 3 Hungarian sporthorse, 1 Hungarian half-bred and 1 Dutch half-bred were included, their progeny number varied between 34 and 156. Among the top three horses there were 2 Holsteiner and 1 Hungarian sporthorse Ramzes III-80 Randi, this fact proves opportunities in the Hungarian breeding in case of show jumping discipline. This fact should be emphasized, because in recent years progenies from the import sires were favoured instead of progenies sired by Hungarian sporthorses. We recommend testing more progenies from Hungarian sporthorses in the show jumping discipline to reach progress in breeding through the more strictly selection.

Estimated breeding value above 120 value with 0.60-0.69 realibility value are also illustrated. We should note that these results are only informative. From these 34 sires there were 5 Hungarian sporthorses, 2 Mezőhegyesi sporthorses, 1 Hungarian half-bred and 1 Kisbéri félvér. Analysis resulted breeding values with two standard deviation unit above the average (at least 140 breeding value) in case of 6 sires. The best sire from the first group (sires having reliable breeding value), and the best sire from the other group (sires having breeding value with 0.6-.069 reliable value) are brothers, Cassini II and Cassini I respectively. (sire Capitol I, dam Wisma).

Evaluation of sport performance with random regression model

The best fitting random regression model was the model with a polynomial of first order fit (LP1) for all random effects. Results for all three weighted measures were similar, that is why results of weighted square root model is presented only.

Performance scores have increased with increasing age, older and experienced horses got higher scores, reached better performance (*Figure 1.*). First at age 5.5 horses reached scores with 2 standard deviation unit above the mean (standard deviation = 9.46), scores with 3-4 standard deviation unit above the mean was shown at 7.5 years old. The highest scores, the best performance were achieved between 9 and 13.5 years old, similarly to the literature.

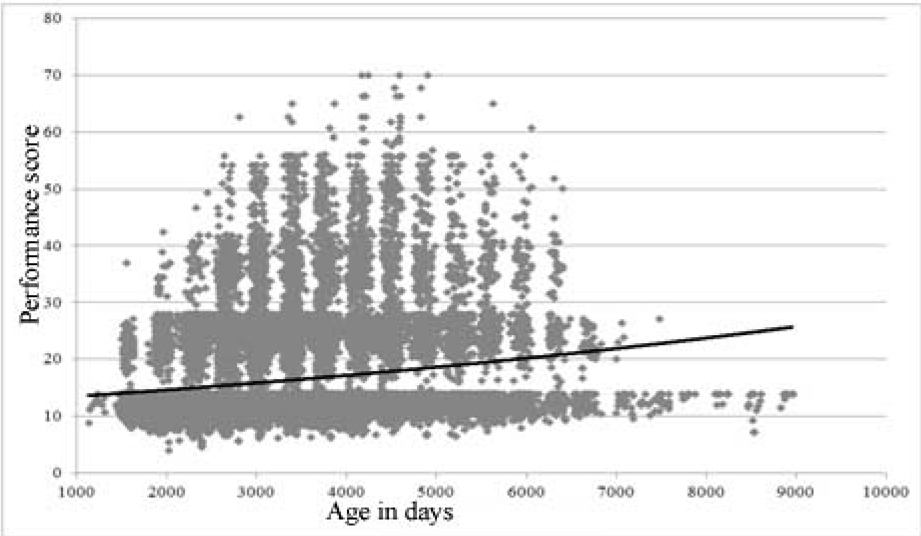

Figure 1.: Relationship between weighted square root rank and age

Genetic variance was increased steadily from 6 years old, hereby the difference between the performances was shown (*Figure 2.*). Homogeneous variance (7.63) was estimated for random effect of the rider. Variance estimated for permanent environmental effect decreased until 6 years old, and was the lowest in the 6-7 years old age classes. The reason can be that a young horse starting its career at 4-5 age and after 2 years becomes more and more experienced and react to the environmental stimuli less, so variability of environment effects will be less. Variance of permanent environmental effect increased from 7 years old, which can be explained as there is a greater variability in perceived stimuli of horses (experiences, condition, health status) at higher competition level.

Variance for error term increased until 9 years old, after that age it was constant. This fact implies the difference between performances are influenced such components (management, training) with increasing age which effect could not be taken into account in the model.

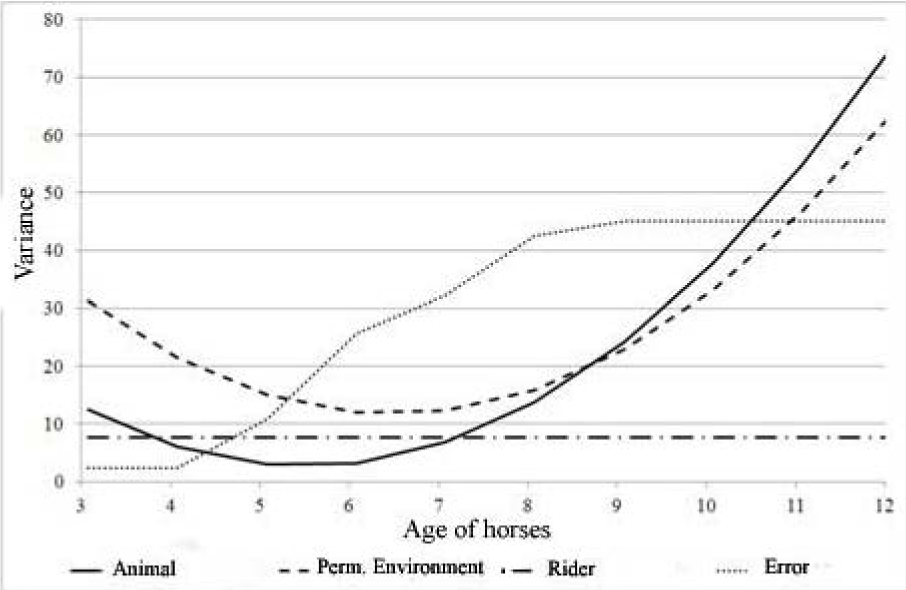

Figure 2.: Variances for random and residual effects estimated with random regression model (LP1)

Heritability value increased from 6 years of age, it varied between h^2 = 0.08 - 0.37 (*Figure 3.*). From 7.5 years of age the animal effect on its performance exceeded the rider effect, the heritability values was greater than the variance proportion of rider effect. The animal had a greater effect in the outcome of the performance, than the permanent environmental effect after 9.5 years of age. Heritability value exceeded the error term proportion of the variance at 11 years of age. As sporthorses was getting older, higher heritability values were estimated, while the variance proportion of the rider effect reduced continuously. Genotype had greater effect on performance than rider effect at older ages, as horses and also riders become more experienced. Variance proportion of permanent environmental effect was the lowest at age between 7-8 years old, while the error term was the highest for these age groups. Variance proportion of error term decreased from 8 years of age, while the proportion of permanent environmental effect started to increase again. Factors that affect the performance of the horses can be more interpretable from 8 years of age through decreasing error term and increasing environmental effect.

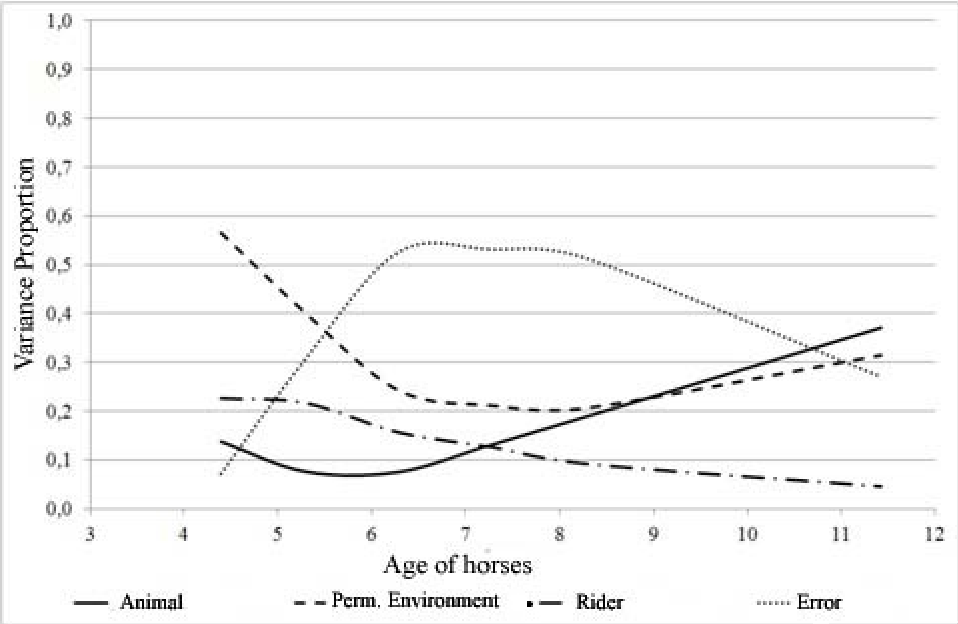

Figure 3.: Variance proportion for random and residual effects estimated with random regression model (LP1)

Strong genetic and phenotypic correlation values were estimated between the neighboring age groups. Genetic and phenotypic correlation between the age groups declined steadily with the increasing age (*Figure 4.*). Weak genetic correlations were estimated between 4–5–6 years of age and older (7, 8, 8+) age classes. Phenotypic correlation was weak similarly between these age groups. Performance reached at younger age (4–5–6 years old horses) do not reflect the later performance at all. Between performance reached at 7 - 8 years old and later performance strong phenotypic correlation value was estimated, while performance reached at 6 years old showed moderate phenotypic correlation value with later performance in the future. So performance at 7-8 years old can refer to the future performance with higher probability. Genetic correlation values were similar.

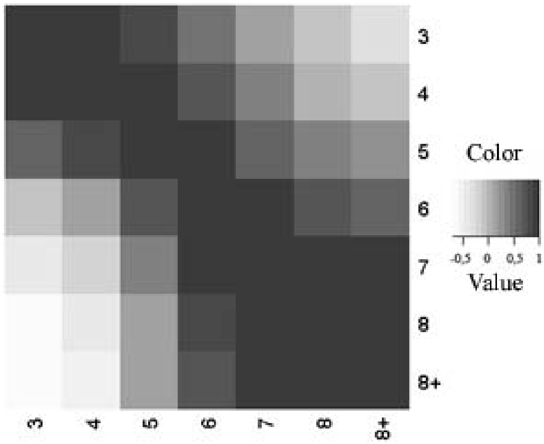

Figure 4.: Genetic correlations (above the diagonal) and phenotypic correlations (below the diagonal) between performances in different age classes

Estimates of the first eigenfunction for weighted square root ranks were positive from age 6.08 (2219 age in days) indicating that selection based on the sport performance traits could be successful from 2219 days old (*Figure 5.*), in other words selection based on this trait at any age from 6.08 should change show-jumping performance in the same direction. For weighted square root ranks the first eigenvalue explained 99.56% of the genetic variation, and the second eigenfunction was responsible for only 0.44% of the total genetic variation for the first ordered Legendre polynomial. Variances explained by eigenfunctions of second order Legendre polynomials were lower, so the first order LP 1 was the best fitting.

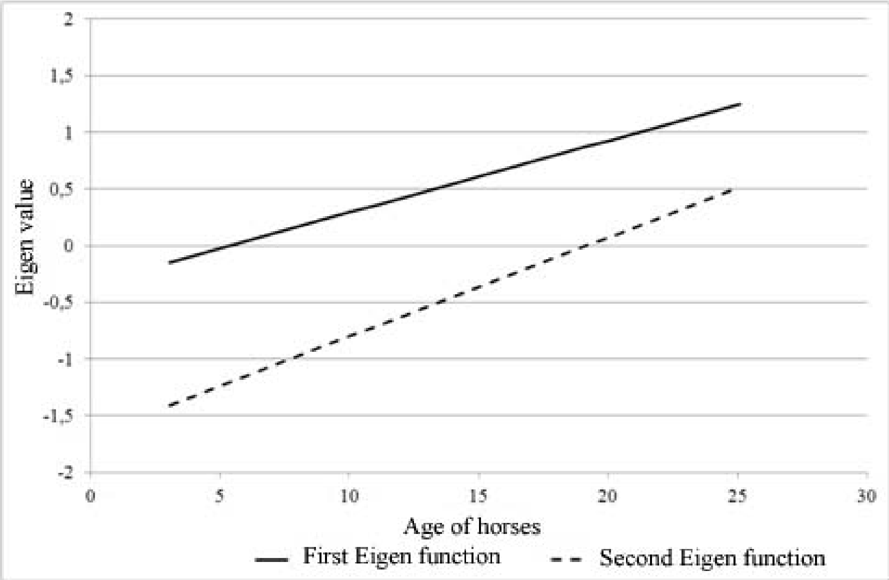

Figure 5.: Eigenfunctions of weighted square root ranks for the random animal effect estimated with random regression model

IV. NEW STATEMENTS OF THE THESIS

I. Evaluating the Hungarian show jumping result between 1996 and 2011, we can conclude that transformation of ranks with square root, logarithmic function, and Blom transformed ranks could be appropriate for measuring the performance of the sporthorses.

II. It is worth considering competition level as a weighting factor calculating the performance score, instead of regarding the difficulty level as fixed effect in the repeatability animal model.

III. Significant and low heritability values (h^2 = 0.02-0.07), and significant and low and moderate repeatability values (R = 0.08-0.25) were estimated for performance traits evaluating the Hungarian show jumping data from period 1996-2011.

IV. Strong phenotypic correlation value was estimated between the performance reached at 7-8 years old and later performance. So performance at 7-8 years old can refer to the future performance with higher probability. At least two years of sports performance is required for effective selection based on show jumping performance in case of a sporthorse starting its career at age 4.

V. PRACTICAL APPLICABILITY OF THE RESULTS

I. Hungarian Sporthorse Breeders can utilize the results in their breeding program and selection decision. Estimated breeding values of the sires can help to choose better breeding animals, and to esteem them, especially the Hungarian breeds. It is recommended to test more progenies from Hungarian sporthorses in the show jumping discipline to reach more reliable information about sires and to reach progress in breeding scheme through the strictly selection. Results can make recommendation for ex-situ gene conservation as well.

II. Stronger phenotypic correlation value was estimated between the performance reached at 7-8 years old and later performance, than performance between at 6 years of age and later performance. So future performance can be predicted with higher probability based on performance at 7-8 years of age. At least two years of sports performance is required for effective selection based on show jumping performance in case of a sporthorse starting its career at age 4.

III. The used repeatability animal model and random regression model are appropriate to measure and evaluate the show jumping performance of the Hungarian show-jumping horses. Application of these models is suggested in practice.

VI. LIST OF PUBLICATIONS

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Registry number: DEENK/158/2015.PL
Subject: Ph.D. List of Publications

Candidate: Anita Rudiné Mezei
Neptun ID: SIG3C3
Doctoral School: Doctoral School of Animal Husbandry
MTMT ID: 10048212

List of publications related to the dissertation

Hungarian book(s) (1)

1. Posta J., **Rudiné Mezei A.**, Mihók S.: Sportlovak díjugratási sporteredményeinek értékelése:(az OTKA PD83885 posztdoktori kutatási pályázat keretében elvégzett kutatás eredményei 2011-2013). DE AGTC Állattenyésztéstani Tanszék, Debrecen, 88 p., 2013. ISBN: 9786155183997

Hungarian scientific article(s) in Hungarian journal(s) (2)

2. Posta J., **Rudiné Mezei A.**, Mihók S.: A díjugrató sportban különböző nehézségi szinteken nyújtott sportteljesítmények értékelése.
Anim. Welf. Etol. Tartástechnol. 9 (3), 294-299, 2013. ISSN: 1786-8440.

3. **Mezei A.**: Lovak tenyészértékbecslése a díjugrató sportban elért teljesítmény alapján:(Irodalmi áttekintés).
Állatteny. Takarm. 60 (2), 185-196, 2011. ISSN: 0230-1814.

Foreign language scientific article(s) in Hungarian journal(s) (2)

4. **Rudiné Mezei, A.**, Posta, J., Mihók, S.: Evaluation of Hungarian show-jumping results using different measurement variables.
Agrártud. Közl. [Debrecen]. 2013 (53), 81-85, 2013. ISSN: 1587-1282.

5. **Rudiné Mezei, A.**, Posta, J., Mihók, S.: Random regression models for genetic evaluation of performance of the Hungarian show-jumping horse population.
Agrártud. Közl. 59, 87-91, 2014. ISSN: 1587-1282.

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Foreign language scientific article(s) in international journal(s) (1)

6. **Rudiné Mezei, A.**, Posta, J., Mihók, S.: Comparison of Different Measurement Variables Based on Hungarian Show Jumping Results.
Ann. Anim. Sci. 15 (1), 177-183, 2015. ISSN: 1642-3402.
DOI: http://dx.doi.org/10.2478/aoas-2014-0063
IF:0.613 (2014)

Hungarian conference proceeding(s) (2)

7. Posta J., **Rudiné Mezei A.**, Mihók S.: A díjugratásban nyújtott teljesítményt értékelő különböző matematikai átalakítások összehasonlítása.
Az LV. Georgikon Napok elektronikus kiadványa 55, 41-50, 2013.

8. Posta J., **Mezei A.**, Mihók S.: Nehézségek a díjugratási sporteredmények számtan-statisztikai értékelésekor:(előtanulmány)..
Az LIII. Georgikon Napok elektronikus kiadványa 53, 595-601, 2011.

List of other publications

Hungarian scientific article(s) in Hungarian journal(s) (3)

9. Posta J., **Rudiné Mezei A.**, Mihók S.: Díjugrató sportban a hasznos élettartam értékelése különböző mérőszámokkal.
Magy. Állatorv. L. 135 (1), 7-11, 2013. ISSN: 0025-004X.
IF:0.185

10. **Rudiné Mezei A.**, Posta J., Mihók S.: Hazai és külföldi tenyésztésű lovak teljesítményének összehasonlítása a díjugrató sportban elért eredmények alapján.
Állatteny. Takarm. 62 (1), 57-69, 2013. ISSN: 0230-1814.

11. **Mezei A.**, Posta J., Mihók S.: Saját- és ivadékteljesítmény vizsgálat a military sportban.
Agrártud. Közl. 48, 49-56, 2012. ISSN: 1587-1282.

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Foreign language scientific article(s) in international journal(s) (1)

12. Posta, J., **Rudiné Mezei, A.**, Mihók, S., Mészáros, G.: Evaluation of the length of competitive life in Hungarian sporthorses.
J. Anim. Breed. Genet. 131, 529-535, 2014. ISSN: 0931-2668.
IF:1.566

Hungarian conference proceeding(s) (2)

13. Posta J., **Mezei A.**, Mihók S.: A díjugrató sportban hasznos élettartam értékelése matematikai mérőszámokkal a magyarországi díjugrató lóállományban.
Az LIV. Georgikon Napok elektronikus kiadványa 54, 405-410, 2012.

14. **Rudiné Mezei A.**, Posta J., Mihók S.: Az import és hazai tenyésztésű lovak értékelése a díjugrató sportban elért teljesítmény alapján.
Az LIV. Georgikon Napok elektronikus kiadványa 54, 411-419, 2012.

Foreign language abstract(s) (4)

15. Posta, J., **Rudiné Mezei, A.**, Mihók, S.: Transformed variables for the genetic evaluation of the competition performance of jumping horses.
Book of abstracts of the 64rd Annual Meeting of the European Association for Animal Production 19, 358, 2013.

16. Posta, J., **Mezei, A.**, Mihók, S.: Mathematical measurement variables for the evaluation of durability of Hungarian Show-jumping horses.
Book of abstracts of the 63rd Annual Meeting of the European Association for Animal Production 18, 35, 2012.

17. Posta, J., **Mezei, A.**, Mihók, S.: Genetic evaluation of competition years, as a kind of measurement of durability in Hungarian show-jumping horses.
Proceedings of the 2nd International Equine Science Meeting 2, 51, 2012.

18. **Mezei, A.**, Posta, J., Mihók, S.: Analysis of eventing competition results of Hungarian Sporthorses.
Proceedings of the 2nd International Equine Science Meeting 2, 48, 2012.

Informational/educational article(s) (3)

19. Mihók S., Posta J., **Mezei A.**: A tenyészértékbecslés jelentősége a sportlovak értékelésében és genetikai előrehaladásában 1. rész.
    Lovas. Élet. XIII (2), 40-41, 2012. ISSN: 1419-5526.

20. Mihók S., Posta J., **Mezei A.**: A tenyészértékbecslés jelentősége a sportlovak értékelésében és genetikai előrehaladásában 2. rész..
    Lovas. Élet. 8 (3), 37-39, 2012. ISSN: 1419-5526.

21. **Mezei A.**, Posta J.: Nemzetközi tudományos lovas konferencia 2012.
    Lovas nemz. 18 (5), 16-17, 2012. ISSN: 1416-2377.

Total IF of journals (all publications): 2,364
Total IF of journals (publications related to the dissertation): 0,613

The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of Web of Science, Scopus and Journal Citation Report (Impact Factor) databases.

17 August, 2015