Evaluation of Hungarian show-jumping results using different measurement variables

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SUMMARY

The aim of the study was to compare different fitted models for show-jumping results of sporthorses and to estimate heritability and repeatability value. Show-jumping competition results collected between 1996 and 2011 were analyzed. The database contained 358 342 starts of 10 199 horses. Identity number, name and gender of the horse, rider, competition year, the level and location of the competition and placing were recorded in the database. To measure performance of horses, placing, number of starters and competition level were used. Competitions were categorized into five groups based on their difficulty level. The used repeatability animal model included fixed effects for age, gender, competition place, year of competition (and competition level in case of non-weighted measurement variables), and random effects for rider, animal and permanent environment effect. Variance components were estimated with VCE-6 software package. The goodness-of-fit of the models was low and moderate. Heritability and repeatability values were low for each measurement variables. The best goodness-of-fit model the weighted square root of placing resulted the highest heritability and repeatability value h^2=0.074 and R=0.296.

Keywords: *show-jumping, sporthorse, performance measurement*

ÖSSZEFOGLALÁS

A tanulmány célja különböző modellek összehasonlítása sportlovak ugrósportban nyújtott teljesítményei alapján, továbbá örökölhetőségi és ismételhetőségi értékek számítása volt. A vizsgálat anyagát az 1996 és 2011 közötti díjugratás szakági eredmények jelentették. Az adatbázis 10 199 ló 358 342 startját tartalmazta, melyben megtalálható volt a ló azonosítója, neve, ivara, lovasának neve, verseny ideje, szintje, helyszíne és helyezés. A különböző modellekben a teljesítmény értékeléséhez az elért helyezést, indulók számát, és verseny nehézségét használtuk fel. A versenyeket nehézségi szintjük szerint öt nehézségi kategóriába soroltuk. Több nehézségi szint egy halmazban történő értékeléséhez súlyoztuk a mérőszámokat a nehézségi kategóriák figyelembevételével. Az adatok értékeléséhez alkalmazott ismételhetőségi egyedmodellben fix hatásként vettük figyelembe a ló életkorát, ivarát, verseny évét, helyszínét (és a verseny nehézségi kategóriáját a nem súlyozott mérőszámok esetében). Véletlen hatásként szerepelt a lovas, ló és állandó környezeti hatás a modellben. A variancia komponenseket VCE-6 szoftver alkalmazásával becsültük. A modellek illeszkedésének jósága alacsony, illetve közepes volt. A díjugratási eredmények örökölhetőségi és ismételhetőségi értékei minden modell esetén alacsonyak voltak. A vizsgált modellek közül a nehézségi kategóriával súlyozott négyzetgyök függvénnyel átalakított helyezések modellje illeszkedett a legjobban. A legnagyobb örökölhetőségi és ismételhetőségi értéket, h^2=0,074 és R=0,296 ugyanez a modell eredményezte.

Kulcsszavak: *díjugratás, sportló, teljesítmény mérőszám*

INTRODUCTION

Many criteria have been proposed to appreciate the individual performance of horses in jumping competition. As no objective metric scale exists to express the horse's performance (Hassenstein et al., 1998), the measurement of competition performance is complicated (Bruns, 1981; Tavernier, 1990). Most used criteria are based on transformations of the ranking, earnings or grading scores of the horses *(table 1)*. These quantitative traits can be considered as repeating measurement during the career of the horse.

Many complex traits studied in genetics have markedly non-normal distributions (Micceri, 1989; Allison et al., 1999), this often implies that the assumption of normally distributed residuals has been violated (Beasley et al., 2009). However, the validity of many statistical tests depends on the assumption that residuals from a fitted model are normally distributed (Berry, 1993).

The residual maximum likelihood (REML) estimation introduced by Patterson and Thompson (1971) has been developed for estimating variance components in linear mixed models (O'Neill, 2010a), which method require the normality prerequisite mentioned above (Oehlert, 2012). Genetic parameters like heritability and repeatability values are derived from estimated variance components.

The aim of the study was to compare different fitted models for show-jumping results of sport horses and to estimate heritability and repeatability value.

MATERIAL AND METHODS

Show-jumping competition results collected between 1996 and 2011 were analyzed. The data used in this study were obtained from the Hungarian Equestrian Federation. The final dataset contained in total 358 342 competition records on 10 199 individual horses after data screening, results were gathered from Hungary and other European countries. Identity number, name and sex of the horse, rider, competition year, the level and location of the competition and placing were recorded in the dataset. Information about pedigree of horses were gathered and set up with help of the National Horse Breeder Information System. The pedigree file contained 39878 animals four generation back.

Table 1.

Transformation methods for evaluating performance at competition in European countries

Transformation(1)	Country(2)	Authors who used the transformation(3)
Square root transformation	Germany	Bugislaus et al. (2005), Hassenstein et al. (1998), Jaitner and Reinhardt (2003), Luehrs Behnke et al. (2002)
	Netherlands	Huizinga and van der Meij (1989), Koenen et al. (1995)
	Denmark	Viklund et al. (2011)
	Poland	Sobczynska and Lukaszewicz (2004)
Normalized scores	Czech Republic	Svobodova et al. (2005)
	Belgium	Janssens et al. (1997)
	Ireland	Aldridge et al. (2000), Reilly et al. (1998)
	United Kingdom	Kearsley et al. (2008)
	Spain	Gómez et al. (2006)

Competitions were categorized into five groups based on their difficulty level. For the evaluation of show- jumping performance, scores were created using transformations of placing and number of starters. Repeatability animal model proposed by Mrode (1996) was fitted for the traits. The model

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

was used for traits without level-transformation (not weighted with the difficulty level of competition), and

$Y_{ijklmnop} = \mu + Age_i + Gender_j + Year_k + Place_l + Rider_n + Perm_o + Animal_o + e_{ijklmnop}$

for traits with level-transformation (weighted with the difficulty level of competition), where

$Y_{ijklmnop}$, $Y_{ijklmnop}$ = the score value representing the performance in a particular trait
μ = population mean,
Age_i= fix effect of age,
$Gender_j$ = fix effect of gender,
$Year_k$ = fix effect of year of competition,
$Place_l$ = fix effect of place of competition,
$Level_m$ = fix effect of difficulty level of competition,
$Rider_n$ = random effects of the rider,
$Perm_o$ = permanent environmental effect,
$Animal_o$ = additiv genetic effect of the animal,
$e_{ijklmnop}$ = random residual effect.

The given repeatability animal models utilizes all relationships between horses in pedigree during the genetic evaluation. The level of significance was determined using SAS PROC GLM (SAS Institute, 1999) for each fixed effect.

Traits for evaluation of show-jumping performance are shown in *Table 2*. As the square root function is strictly monotonic, the transformed rank at finish was subtracted from constant 15, thus horses with better placing received higher scores. The constant value can be defined that the final score will be non-negative value (Bugislaus et al., 2005).

Traits based on rank at finish do not take into account the number of starters, thus traits which depend on placing and number of competing horses, were also investigated. The most commonly used rank-based inverse normal transformation entails creating a modified rank variable and then computing a new transformed value (Beasley et al., 2009) of the phenotype for the i-th subject

where

$$Y_i^j = \phi^{-1}\left(\frac{r_i - c}{N - 2c + 1}\right)$$

Y_i^J = the phenotype for the i-th subject,
R_i = the ordinary rank of the i-th case (rank at finish),
N = number of observations (number of starters),
$Ø^{-1}$ = the standard normal probit function,
c = a constant value.

Tukey (1962) proposed the value 1/3 for c, van der Waerden (1952) suggested c=0. The Tukey and Waerden scores take into account not only the placing of the horse but the number of starters also. The Hungarian grading scores (Díjugrató Szabályzat, 2012) based on rank at finish and number of starters was also included in our investigation.

The traits in 2nd, 4th, 6th, and 8th measurement were performed with level-transformation, because results of different horses can be compared within a level. Recordings at higher levels need to be upgraded (Ducro, 2011). As placings do not reflect the level at which the result has been obtained, an alternative way for transformation of performance measurement traits is using different weights for different difficulty levels. In this way if two horses obtained the same placing, the horse competing at higher level will receive higher scores. Other option can be performance at different levels can be considered as different traits and analyze in a multivariate analysis (Hassenstein et al., 1998; Huizinga and van der Meij, 1989; Aldridge et al., 2000).

The goodness-of-fit of the models was assessed by using coefficient of determination. Variance components and standard errors were estimated with a repeatability animal model (mentioned before) using the REML method with VCE-6 (Kovac and Groeneveld, 2003) software package. Genetic parameters were predicted from the estimated variance components.

Heritability value (h^2):

$$h^2 = \frac{\sigma_a^2}{\sigma_a^2 + \sigma_p^2 + \sigma_e^2}$$

where σ^2_a is the additive genetic variance, σ^2_p is the permanent environmental variance, and σ^2_e is the residual variance.

Repeatability value (R):

$$R = \frac{\sigma_a^2 + \sigma_p^2}{\sigma_a^2 + \sigma_p^2 + \sigma_e^2}$$

where σ^2_a is the additive genetic variance, σ^2_p is the permanent environmental variance, and σ^2_e is the residual variance.

RESULTS

Fixed effects were significant in all fitted models *(table 2)*. The goodness-of-fit in case of the 1st, 3rd, 4th, 5th and 7th measurement was low $R^2 = 0.07–0.18$; while 2nd, 6th and 8th measurements had moderate $R^2 = 0.45–0.47$ value. The goodness-of-fit values were higher in case of weighted measurement variables, where level-transformation was used.

The Kolmogorov-Smirnov normality test resulted the distribution of the residuals follow normal distribution in all traits ($P<0.01$). Model assumptions can be checked using histograms of residuals (O'Neill, 2010b). The distributions of residuals are demonstrated in *figure 1.*

Estimated heritability and repeatability values are represented in *table 3*. Heritabilities are significantly different from zero, and low 0.01–0.07. The low heritability values show the high impact of various non-genetic (environmental) effects on the show-jumping competition performance. The biggest values of heritability and repeatability were in the 2nd, 6th and 8th measurement.

Heritabilities based on square root of placing were similar to those of Bugislaus et al. (2005) $h^2=0.05–0.07$; and were lower to those of Luehrs Behnke et al. (2002) $h^2=0.11$; Jaitner and Reinhardt (2003) $h^2=0.10$; Sobczynska and Lukaszewicz (2004) $h^2=0.15$; and Viklund et al. (2011) $h^2=0.11$.

Klatt (1979), Meinardus (1988) and Sprenger (1992) reported similarly low values $h^2=0.02–0.06$ based on absolute rankings.

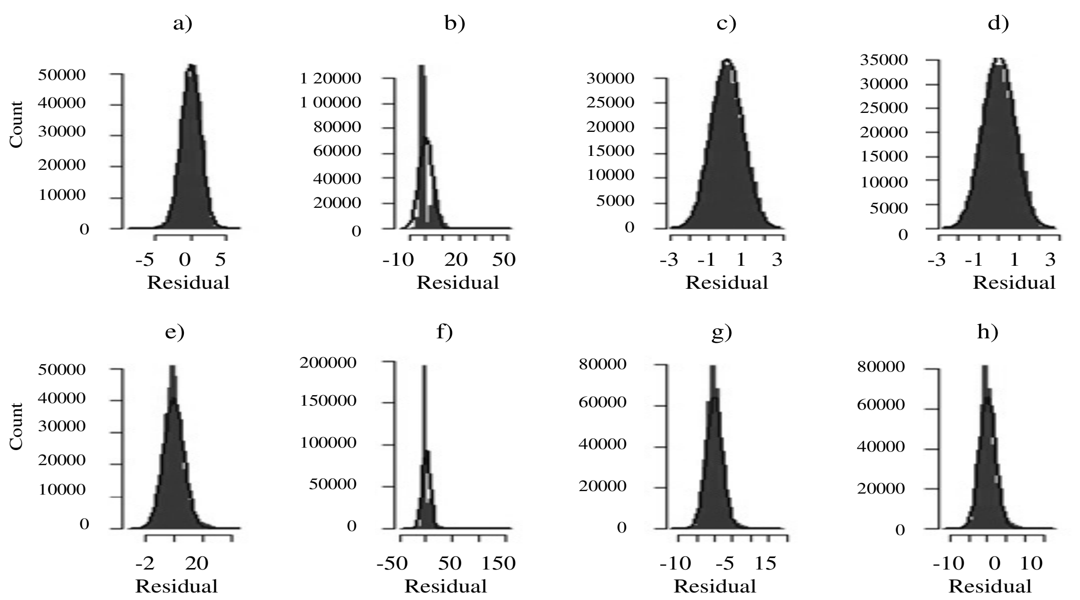
Considering performance at different competition level as different traits, estimated heritability based on square root transformation of ranking was low in Hassenstein et al. (1998) $h^2=0.07–0.11$; in Huizinga and van der Meij (1989) $h^2=0.10–0.20$; in Koenen et al. (1995) $h^2=0.17$.

Table 2.

Traits used for evaluation of show-jumping performance and significance level of fixed effects

Trait(1)	Age(2)	Gender(3)	Year(4)	Place(5)	Level(6)	R^2(7)
15 – square root of placings (1st measurement)(8)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.18
(15 – square root of placings) * difficulty category (2nd measurement)(9)	<0.0001	<0.0001	<0.0001	<0.0001	-	0.47
Hungarian grading scores (3rd measurement)(10)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.07
Hungarian grading scores * difficulty category (4th measurement)(11)	<0.0001	<0.0001	<0.0001	<0.0001	-	0.10
Waerden normalized scores (5th measurement)(12)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.09
Waerden normalized cores * difficulty category (6th measurement)(13)	<0.0001	<0.0001	<0.0001	<0.0001	-	0.46
Tukey normalized scores (7th measurement)(14)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.09
Tukey normalized scores * difficulty category (8th measurement)(15)	<0.0001	<0.0001	<0.0001	<0.0001	-	0.45

Figure 1: **Distribution of the residuals**



Note: non-weighted square-root transformation(a), non-weighted Hungarian scores(b), non-weighted Tukey scores(c), non-weighted Waerden scores(d), weighted square-root transformation(e), weighted Hungarian scores(f), weighted Tukey scores(g), weighted Waerden scores(h).

Table 3. **Heritability and repeatability values of the traits (standard errors within parenthesis)**

Trait(1)	Heritability value(2) [standard error(3)]	Repeatability value(4)
15 – square root of placings(5)	0.024 (0.003)	0.090
(15 – square root of placings) * difficulty category(6)	0.074 (0.007)	0.296
Hungarian grading scores(7)	0.023 (0.003)	0.065
Hungarian grading scores * difficulty category(8)	0.014 (0.002)	0.053
Waerden normalized scores(9)	0.053 (0.005)	0.133
Waerden normalized cores * difficulty category(10)	0.072 (0.007)	0.271
Tukey normalized scores(11)	0.052 (0.005)	0.131
Tukey normalized scores * difficulty category(12)	0.070 (0.006)	0.264

Measuring show-jumping performance as normalized scores, Janssens et al. (1997) published h^2=0.02–0.10, Aldridge et al. (2000) h^2=0.07–0.10; Svobodova et al. (2005) h^2=0.17. Considering performance at different competition level as different traits, estimated heritability based on normalized scores Kearsley et al. (2008) found higher values h^2=0.08–0.23.

Repeatabilities based on square root of ranking were similar to those of Bugislaus et al. (2005) R=0.20–0.24; Jaitner and Reinhardt (2003) R=0.31; Sobczynska and Lukaszewicz (2004) R=0.33. Repeatabilities based on normalized scores were similarly low to Janssens et al. (1997) R=0.09–0.27, and Svobodova et al. (2005) R=0.32.

Considering performance at different competition level as different traits, estimated repeatability based on square root of ranking was R=0.14–0.21 in Hassenstein et al. (1998), estimated repeatability based on absolute ranking was R=0.09 in Meinardus (1988).

CONCLUSIONS

During the measurement of show-jumping performance with different traits, it is worth to use competition level as weighting factors. Fitting models for weighted scores had better goodness-of-fit value. The best goodness-of-fit value were in case of weighted square root, weighted Tukey and weighted Waerden transformation, the biggest heritability and repeatability values were estimated in these models also. Estimated heritability for show-jumping performance traits were low (h^2=0.01–0.07) for each measurement variable. The repeatability values were more favourable R=0.09–0.30. The best measure of show-jumping performance was the weighted square root transformation of placing.

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REFERENCES

Aldridge, L. I.–Kelleher, D. L.–Reilly, M.–Brophy, P. O. (2000): Estimation of the genetic correlation between performances at different levels of show jumping competition in Ireland. J. Anim. Breed. Genet. 117: 65–72.

Allison, D. B.–Neale, M. C.–Zannolli, R. Z.–Schork, N. J.–Amos, C. I.–Blangero, J. (1999): Testing robustness of the likelihood ratio test in a variance-component quantitative trait loci (QTL) mapping procedure. Am. J. Hum. Genet. 65: 531–544.

Beasley, T. M.–Erickson, S.–Allison, D. B. (2009): Rank-based inverse normal transformations are increasingly used, but are they merited? Behav. Genet. 39: 580–595.

Berry, W. D. (1993): Understanding regression assumptions. Sage University Paper series on Quantitative Applications in the social sciences, 07–092. Newbury Park. CA: Sage.

Bruns, E. (1981): Estimation of the breeding value of stallions from the tournament performance of their offspring. Liv. Prod. Sci. 8: 465–473.

Bugislaus, A. E.–Roehe, R.–Kalm, E. (2005): Comparison of two different statistical models considering individual races or racetracks for evaluation of German trotters. Liv. Prod. Sci. 92: 69–76.

Díjugrató Szabályzat (2012): www.dijugratoszakag.hu

Ducro, B. J. (2011): Relevance of test information in horse breeding. Thesis. Wageningen University, Wageningen. 170.

Gómez, M. D.–Cervantes, I.–Bartolomé, E.–Molina, A.–Valera, M. (2006): Genetic evaluation of show-jumping performance in young Spanish sporthorse. 57th Annual Meeting of the EAAP. 17–20 September. Antalya. Turkey.

Hassenstein, C.–Roehe, R.–Kalm, E. (1998): Estimation of genetic parameters of German sport horses accounting for competition in the statistical model. Proc. of the 6th World Congr. Genet. Appl. Livest. Prod. Armidale. Australia. 24. 11–16. January. 436–439.

Huizinga, H. A.–van der Meij, G. J. W. (1989): Estimated parameters of performance in jumping and dressage competitions of the Dutch Warmblood horse. Liv. Prod. Sci. 21: 333–345.

Jaitner, J.–Reinhardt, F. (2003): National genetic evaluation for horses is Germany. 54th Annual Meeting of the EAAP. August 31–September 3. Roma. Italy.

Janssens, S.–Geysen, D.–Vandepitte, W. (1997): Genetic parameters for show jumping in Belgian Sporthorses. 48th Ann. Meet. EAAP. 25–28 August. Vienna. Austria.

Kearsley, C. G. S.–Woolliams, J. A.–Coffey, M. P.–Brotherstone, S. (2008): Use of competition data for genetic evaluations of eventing horses in Britain: Analysis of the dressage, show-jumping and cross country phases in eventing competition. Liv. Sci. 118: 72–81.

Klatt, M. (1979): Zuchtwertschätzung von Reitpferdehengsten anhand der Leistungen ihrer Nachkommen auf Turnieren. Diss. Inst. für Tierzucht u. Haustiergenetik. Göttingen.

Koenen, E. P. C.–van Veldhuizen, A. E.–Brascamp, E. W. (1995): Genetic parameters of linear scored conformation traits and their relation to dressage and show-jumping performance in the Dutch Warmblood riding horse population. Liv. Prod. Sci. 43: 85–94.

Kovac, M.–Groeneveld, E. (2003): VCE-5 User's guide and reference manual version 5.1. Institute of Animal Science Federal Agricultural Research Center (FAL). Neustadt. Germany.

Luehrs-Behnke, H.–Roehe, R.–Kalm, E. (2002): Genetic associations among traits of the new integrated breeding evaluation method used for selection of German Warmblood horses. Veterinarija Zootechnika. 18. 40: 90–93.

Meinardus, H. (1988): Züchterische nutzung der Turniersportprüfung für Reitpferde. Genetische Parameter und Zuchtwertschätzung nach einem Blup-Tiermodell. Diss. Georg-August-Universität Göttingen. 169.

Micceri, T. (1989): The unicorn, the normal curve, and other improbable creatures. Psychol. Bull. 105: 156–166.

Mrode, R. A. (1996): Linear models for the prediction of animal breeding values. Editor CAB International UK.

Oehlert, G. W. (2012): A few words about REML. University of Minnesota. Statistics Handout. 11.

O'Neill, M. (2010a): ANOVA&REML A guide to linear mixed models in an experimental design context. Statistical Advisory & Training Service Pty Ltd. 172.

O'Neill, M. (2010b): Regression & Generalized linear (mixed) models. Statistical Advisory & Training Service Pty Ltd. 63.

Patterson, H. D.–Thompson, R. (1971): Recovery of inter-block information when block sizes are unequal. Biometrika. 58: 545–554.

Reilly, M.–Foran, M. K.–Kelleher, D. L.–Flanagan, M. J.–Brophy, P. O. (1998): Estimation of genetic value of show-jumping horses from the ranking of all performances in competition. J. Anim. Breed. Genet. 115: 17–25.

SAS Institute Inc. (1999): SAS/STAT Software Release 8.2 Cary NC. USA.

Sobczynska, M.–Lukaszewicz, M. (2004): Genetic parameters of racing merit of thoroughbred horses in Poland. J. Anim. Breed. Genet. 121: 302–306.

Sprenger, K. U. (1992): Zuchtwertschtzung in der Reitpferdezucht auf der Basis turniersportlicher Lesitungsergebnisse. Diss. Sc. Agr. Leipzig.

Svobodova, S.–Blouin, C.–Langlois, B. (2005): Estimation of genetic parameters of Thoroughbred racing performance in the Czech Republic. Anim. Res. 54: 499–509.

Tavernier, A. (1990): Estimation of breeding value of jumping horses from their ranks. Liv. Prod. Sci. 26: 277–290.

Tukey, J. W. (1962): The future of data analysis. Ann Math Stat. 33: 1–67.

Viklund, A.–Furre, S.–Philipsson, J.–Vangen, O. (2011): Nordic Interstallion – Competition data. Workshop on "Linear scoring in evaluation of sport horses – experiences of current practices and potential developments". 15–16 December. Stockholm. Sweden.

Waerden, B. L. van der (1952): Order tests for the two-sample problem and their power. Proc. Koninklijke Nederlandse Akademie van Wetenschappen. Ser. A. 55: 453–458.