# GENETIC ASSOCIATIONS AMONG TRAITS OF THE NEW INTEGRATED BREEDING EVALUATION METHOD USED FOR SELECTION OF GERMAN WARMBLOOD HORSES

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**Abstract.** In Germany, a new integrated breeding value estimation is based on a multiple-trait animal model, simultaneously considering information from performance test of stallions on station, performance test of mares as well as competition results of sport horses. The objective of this study was to estimate the genetic parameters of the traits used in the integrated breeding evaluation including all German warmblood breeds. The analysed data consisted of 4527, 40670 and 6.000 000 records of performance tests of stallions, mares and of competition results, respectively. Genetic parameters were estimated with a multivariate BLUP animal model. Heritabilities for traits obtained from stallions tested on station ranged from 0.33 (jumping under rider) to 0.51 (trot) and for the traits from mare performance test from 0.27 (walk) to 0.38 (trot). Genetic correlations between corresponding traits recorded on performance test of stallions and mares ranged from 0.87 (canter) to 0.98 (free jumping). Heritabilities of competition traits from horses (build up for sport) were estimated as 0.12 and 0.11 for dressage and jumping, respectively. The use of all traits for estimation of genetic values of horses is expected to reduce pre-selection and it optimal by combines all information resources based on the estimated genetic parameters.
**Keywords:** genetic parameters; breeding value estimation; selection; horse

## GENETINIŲ RYŠIŲ TARP POŽYMIŲ TYRIMAS NAUJU INTEGRUOTO VEISLINĖS VERTĖS ĮVERTINIMO METODU, VYKDANT VOKIETIJOS KARŠTAKRAUJŲ ARKLIŲ SELEKCIJĄ

**Santrauka.** Naujas integruotas veislinės vertės nustatymo metodas yra pagrįstas kelių gyvulio požymių vertinimo modeliu, apimančiu informaciją apie eržilų ir kumelių darbinių savybių išbandymų ir sportinių arklių konkursų rezultatus. Šio darbo tikslas buvo įvertinti požymių, naudotų visų Vokietijos karštakraujų arklių veislių integruotam veislinės vertės nustatymui, genetinius rodiklius. Analizuoti 4527 eržilų, 40 670 kumelių darbinių savybių išbandymų ir šešių milijonų sportinių arklių varžybų rezultatai. Genetiniai rodikliai apskaičiuoti pagal multivariacinį *BLUP* modelį. Eržilų požymių paveldimumas įvairavo nuo 0,33 (šuolis su raiteliu) iki 0,51 (risčia), kumelių – nuo 0,27 (žinginė) iki 0,38 (risčia). Genetinė atitinkamų eržilų ir kumelių požymių, nustatytų darbinių savybių išbandymų metu, koreliacija įvairavo nuo 0,87 (galopas) iki 0,98 (laisvas šuolis). Arklių konkursinių požymių (pvz., tinkamumo dresūrai ir judrumo) paveldimumas buvo atitinkamai 0,12 ir 0,11. Tikimasi, kad arklių genetinės vertės nustatymo pagal daugelį požymių modelis padės sumažinti pirminę selekciją ir optimaliai suderinti visus duomenis, pagrįstus apskaičiuotais genetiniais rodikliais.
**Raktažodžiai:** genetiniai parametrai, veislinės vertės nustatymo metodas, selekcija, arkliai

**Introduction.** In Germany, the main disadvantage of the past breeding value estimation for competition is the pre-selection of horses regarding their suitability and talent for the sport discipline: jumping or dressage. In addition, only the best 25% of the started horses, the placed horses, could be considered by the trait natural logarithm earnings of placing. By this pre-selection the genetic variance will be underestimated and the breeding values of the horses biased.

At present, data which were collected by TORIS (Turnier-, ORganisations- und InformationsSystem) can be used. TORIS is a competition-program from the German FN (Federation Equestre Nationale) in which the promoters are recording the results at competition [Hassenstein, 1998]. Thus, all started horses can be considered in the analyses. The trait square root of place was developed and there is a gain of information through the consideration of all starters [Hassenstein, 1998]. The stallion and mare performance tests deliver early

information in regard to the predisposition for the sport discipline dressage and jumping. High genetic correlations were determined between the corresponding traits of stallion performance test and the tournament competitions as well as competitions for young inexperienced horses, respectively [Schade, 1996; Brockmann, 1998]. There were very high genetic correlations between the traits of stallion and mare performance test [Velsen-Zerweck and Bruns, 1998]. On the bases of high genetic correlations between the stallion performance test and competition results these authors concluded [Schade, 1996] that traits of the mare performance test were also highly associated with competition performances.

Because of the numerous relationships among different traits of different performance tests and competitions, a new integrated breeding value estimation is developed. The new integrated breeding value estimation is based on a multiple-trait repeatability animal

model, simultaneously considering information from performance test of mares, performance test of stallion on station as well as all competition results of sport horses (including non placed horses). Due to the simultaneous consideration of observations from mare and stallion performance tests as well as the competition results of sport horses, a gain of information and accuracy will be achieved, and the bias of breeding values due to pre-selection - reduced.

At present, the used heritabilities for the new integrated breeding value estimation originate only from literature. Heritabilities and genetic correlations have to be estimated on the population of interest. Therefore, it is necessary to estimate the genetic parameters on the basis of the whole data used for the integrated breeding value estimation. The objective of this study was to estimate genetic parameters of these traits used in the integrated breeding evaluation including all German warmblood breeds.

**Materials and methods.** Data of the integrated breeding value estimation and the following analyses are as follows:

- stallion performance tests from 1986 until 2001 (4527 stallions),
- mare performance tests from 1986 until 2001 (40,670 mares),
- results from competitions for young horses, which were build up for sport, from 1995 until 2001 (204,669 observations for dressage and 786,513 observations for show jumping)
- results from competitions of experienced horses from 1995 until 2001 (1,408,654 observations for dressage and 3,515,070 observations for show jumping)

The 15 traits used in the integrated breeding evaluation are walk, trot, canter, rideability and free jumping from mare performance test and walk, trot, canter, rideability, free jumping and jumping under rider from stallion performance test. The four traits obtained from sport are dressage competition, show jumping competition for experienced horses as well as dressage and show jumping competition for young horses, which were build up for sport.

For mare and stallion performance tests and competitions for young horses the recorded scores of the traits were used; for dressage and show jumping competition the transformed rank was used, which was the square root of place ($y*=11-y^{0,5}$). The statistic program package SAS [SAS Institut Inc., 2000] was used for the data preparation. For estimation of variance components, a multiple-trait animal model was fitted using multivariate REML program VCE 4.2.5 [Groeneveld, 1998].

The model for traits of stallion performance test and mare performance test is as follows:

$$Y_{ij} = \mu + P_i + a_j + e_{ij} \qquad \text{(I)}$$

where $Y_{ij}$ is the observed score of each trait for the jth animal; $\mu$ is the population mean; $P_i$ is the fixed effect of the ith test group; $a_j$ is the random additive genetic effect of the jth horse; $e_{ij}$ is the random residual effect.

The model for traits of competition of experienced horses and competitions for young horses, which were build up for sport is:

$$Y_{ijklm} = \mu + P_i + A_j + R_k + p_l + a_m + e_{ijklm} \qquad \text{(II)}$$

where $Y_{ijklm}$ is the observed score of each trait for the mth animal; $\mu$ is the population mean; $P_i$ is the fixed effect of the ith competition; $A_j$ is the fixed effect of the jth combination of sex and age; $R_k$ is the fixed effect of the kth combination of the performance group of the rider and year or the rider directly, if the rider had enough starts with different horses in the same year (competition of experienced horses at least 50 starts with not less than five horses and competition for young horses at least 30 starts with not less than three horses); $p_l$ is the random effect of the lth permanent environment of the horse; $a_m$ is the random additive genetic effect of the mth horse; $e_{ijklm}$ is the random residual effect.

**Results.** Table 1 shows heritabilities and genetic correlations between the traits of stallion performance test. Heritabilities varied between 0.33 and 0.51. There were high genetic correlatios among the dressage traits (walk, trot, canter and rideability). While walk and trot had low negative correlations to free jumping, canter showed a low positive correlation to free jumping. Canter and rideabilty were moderately correlated with jumping under rider. Whereas free jumping and jumping under rider were closely genetically related.

Heritabilities and genetic correlations for traits from mare performance test are presented in Table 2. Heritabilities ranged from 0.27 to 0.38. Similar to the results of the stallion performance test, genetic correlations among the dressage traits were high. In contrast to stallion performance test, genetic relations of the gaits and rideability to free jumping were positive for mare performance test.

Table 1: **Heritabilities (h$^2$, diagonal) and genetic correlations (r$_g$) for traits of stallion performance test (SPT), (years 1986-2001; n=4527)**

| Trait | SPT walk | SPT trot | SPT canter | SPT rideability | SPT free jumping | SPT jumping under rider |
|---|---|---|---|---|---|---|
| SPT walk | *0.34* | 0.75 | 0.74 | 0.67 | -0.15 | 0.03 |
| SPT trot | | *0.51* | 0.85 | 0.84 | -0.06 | 0.03 |
| SPT canter | | | *0.42* | 0.83 | 0.19 | 0.33 |
| SPT rideability | | | | *0.41* | 0.04 | 0.21 |
| SPT free jumping | | | | | *0.39* | 0.94 |
| SPT jump. u. rider | | | | | | *0.33* |

SE (h$^2$): 0.02; SE (r$_g$): 0.01–0.04

Table 2. **Heritabilities ($h^2$, diagonal) and genetic correlations ($r_g$) for traits of mare performance test (MPT), (years 1986-2001; n=39348)**

| Trait | MPT walk | MPT trot | MPT canter | MPT rideability | MPT free jumping |
|---|---|---|---|---|---|
| MPT walk | *0.27* | 0.66 | 0.64 | 0.69 | 0.12 |
| MPT trot | | *0.38* | 0.82 | 0.81 | 0.21 |
| MPT canter | | | *0.34* | 0.82 | 0.30 |
| MPT rideability | | | | *0.29* | 0.20 |
| MPT free jumping | | | | | *0.32* |

SE ($h^2$): 0.01; SE ($r_g$): 0.01–0.02

Table 3: **Genetic correlations ($r_g$) between traits of stallion performance test (SPT) and mare performance test (MPT), (years 1986-2001; SPT: n=4527; MPT: n=39348)**

| Trait | SPT walk | SPT trot | SPT canter | SPT rideability | SPT free jumping | SPT jumping under rider |
|---|---|---|---|---|---|---|
| MPT walk | - | 0.66 | 0.75 | 0.62 | -0.05 | 0.05 |
| MPT trot | 0.65 | - | 0.79 | 0.74 | 0.05 | 0.13 |
| MPT canter | 0.59 | 0.70 | - | 0.69 | 0.17 | 0.34 |
| MPT rideability | 0.69 | 0.80 | 0.87 | - | 0.02 | 0.21 |
| MPT free jumping | -0.09 | 0.04 | 0.14 | 0.07 | - | 0.86 |

SE ($r_g$): 0.01–0.04

Table 4. **Genetic correlations ($r_g$) between corresponding traits of stallion performance test (SPT) and mare performance test (MPT), (years 1986-2001; SPT: n=4527; MPT: n=39348)**

| Trait | Genetic correlation SPT:MPT | SE |
|---|---|---|
| Walk | 0.88 | 0.03 |
| Trot | 0.90 | 0.02 |
| Canter | 0.87 | 0.03 |
| Rideability | 0.91 | 0.03 |
| free jumping | 0.98 | 0.02 |

SE ($r_g$): 0.02–0.03

Table 5. **Heritabilities ($h^2$) and standard error (SE) for competitions for young inexperienced horses**

| | observations | $h^2$ | SE |
|---|---|---|---|
| Dressage competition for young horses | 92332 | 0.12 | 0.01 |
| Show jumping competition for young horses | 74076 | 0.11 | 0.01 |

Genetic associations among traits from stallion and mare performance test are given in Table 3. Genetic correlations between the dressage traits recorded on stallion and mare performance tests were nearly on as high level as in the specific performance tests. The gaits and rideability were genetically low related to free jumping at different performance tests, for which canter resulted in the highest values. Genetic correlations between the dressage traits from mare performance test and jumping under rider from stallion performance test ranged from low to medium level. Free jumping from a mare performance test was genetically very high related to jumping under rider from stallion performance tests.

In Table 4 present the genetic correlations among corresponding traits from stallion and mare performance tests. The correlations were on a very high level and ranged from 0.87 to 0.98 (free jumping).

Heritabilities and standard errors for competitions of young inexperienced horses are presented in Table 5.

Heritabilities for dressage as well as of jumping competition of young horses were on low level and their standard error were low.

**Discussion and conclusion.** Genetic correlations of traits from stallion performance tests comply with the results reported by Brockmann (Brockmann, 1998). Generally heritability for jumping traits were a little lower in the present study. The heritabilities and genetic correlations for the gaits and rideability from mare performance test correspond with the results from earlier publications (heritabilties: (Velsen-Zerweck and Bruns, 1998), genetic correlations: (Schade, 1996)). In the literature the differences between estimates of genetic correlations between the dressage traits and free jumping are remarkable. On the basis of data from the Hanoverian studbook negative genetic correlations between walk and free jumping were determined (Schade, 1996). In the latter study other dressage gaits showed low genetic relations to free jumping. Using data from the Holstein

studbook, genetic correlations between the dressage traits and free jumping were of moderate magnitude ($r_g$: 0.22-0.48) (Boesch et al., 2000). In the present study, the genetic correlations between the dressage traits and free jumping ranged from 0.12 to 0.30. Obviously, there are differences between the German warmblood breeds. In the present study, about 40% of the mares in the data were tested by the Hanoverian studbook. Therefore, it will be necessary to investigate whether a single German warmblood breed influenced mainly the overall estimates and whether different parameters have to be used for different breeds.

In one of the latest studies about correlation among traits recorded on stallion and mare performance test, only the tested mares of the Hanoverian studbook were considered (Schade, 1996). In the present study, the clearly higher positive genetic correlation between walk and other gaits or rideability of different performance tests is remarkable. Negative correlations between the dressage traits from mare performance test and the trait of jumping from stallion performance test in the previous study determined cannot be verified by this study. Walk, trot and rideability from mare performance test seems not to be related to free jumping from stallion performance test. Canter from mare performance test was moderately positively correlated to the jumping traits from stallion performance test.

In a recent study, genetic correlations between corresponding traits of stallion and mare performance test were estimated on the basis of mare performance test data from six German warmblood studbooks and data of stallion performance test from the year 1986 until 1995 (Velsen-Zerweck and Bruns, 1998). Genetic correlations calculated in the present study exceeded the genetic correlations of the above mentioned study, which were considerably high. These very high genetic correlations indicate the similarity of the traits of stallion and mare performance test.

In the first analysis for competitions of young inexperienced horses with data about all started horses, for dressage and jumping competition of young horses heritability were estimated with $h^2$=0.35 and $h^2$=0.14, respectively (Brockmann, 1998). In the present study, heritability for dressage competition for young horses was substantially lower. The difference could have been caused by insufficient data structure of the previous study, because at that time only about ten percent of the whole data could have been used (Brockmann and Bruns, 1998).

The present study verifies earlier studies about the importance of stallion and mare performance test for breeding. The heritabilities for the traits of stallion and mare performance tests were on moderate magnitude, and therefore, allow successful work in breeding. It is shown that traits measured in stallion and mare performance tests reflect the same traits even though they were measured in different environments and different sexes.

The use of all traits for estimation of genetic values of horses is expected to reduce pre-selection and it optimally combines all information resources based on estimated genetic parameters. Because of the simultaneous consideration of the available performance and competition results, there is a gain of information and accuracy. At present the total breeding value of dressage from the integrated breeding value estimation is formed in equal parts from the individual breeding values of performance test of mares and stallions and information from dressage competition of inexperienced young horses and dressage competition of experienced horses. The specific gaits and the rideability influence similarly the breeding value of dressage of the stallion and mare performance tests. Similar to the total breeding value of dressage, the total breeding value jumping is determined out of the individual breeding values of jumping. The single breeding value of stallion performance test is formed from the free jumping and the jumping under rider.

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2002 06 19