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GENETIC CORRELATIONS BETWEEN MOVEMENT AND FREE-JUMPING TRAITS AND PERFORMANCE IN SHOW-JUMPING AND DRESSAGE COMPETITION OF DUTCH WARMBLOOD HORSES

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INTRODUCTION

The breeding objective of the Royal Dutch Warmblood Studbook (KWPN) includes sport performance, health and conformation traits. KWPN invokes a horse that can act at the highest level in competition, with an aesthetic and functional conformation (KWPN, 1994). Knowledge of genetic parameters is essential for purposes such as evaluation of breeding plans, prediction of breeding values and prediction of response to selection. KWPN estimates the breeding values based on performance in dressage and show-jumping at competitions. However, performance traits have low heritabilities (Huizinga and Van der Meij, 1989), and can be measured only late in life. Inclusion of the performance of progeny for improving the accuracy of the breeding values would only extend the generation interval. Alternatively, traits recorded at performance tests of young horses has approved to be good predictors of sport performance later in life (Thorén et al., 2005) and KWPN has extended its breeding programme with this information from performance tests.
A further improvement of the genetic evaluation procedures could be achieved by including information from studbook entrance classifications. In the breeding programme of the KWPN, young horses are classified prior to entrance in the studbook at three years or older. A linear descriptive scoring system was introduced in horse breeding by the KWPN in 1989. A classifier fills in the linear scoring-sheet, with scores for traits related to conformation, movements and free-jumping. In 1992 the subjective traits conformation and movement were added.
The movement and free-jumping of a young horse is expected to be an indicator for subsequent performance. The efficiency of indirect selection for performance depends on the genetic variation of conformation and movement traits and on the genetic correlations between conformation and movement traits and performance traits.
A first genetic evaluation of the linear scoring traits recorded at studbook entrance showed that indirect selection on these traits would only result in a limited improvement of performance in competition (Koenen et al., 1995). In 1998 a part of the linear scoring traits were modified and new traits on canter and jumping were added. Also the subjective trait free-jumping was added. The new traits have been carefully selected, based on analysis of the previous 30 conformation traits, for its potential to predict performance in competition.

The objectives of this study were to estimate the heritabilities for the traits related to movement and free-jumping of the studbook-entry and to estimate the genetic correlations of these traits to performance in dressage and show jumping competition.

MATERIAL AND METHODS

At studbook entrances, which are held at different locations in the Netherlands, a classifier gives each horse one score per trait. The score is a linear descriptive value on a scale that reflects the biological range in the population. It thus tells how the horse is located relative to the population extremes for that trait, irrespective of what is desired for that trait. For the descriptive traits scores are on a 1 to 40 scale, with an increment of 1. The score of 20 points reflects the average KWPN horse. For most traits, the scale is such that a score below the average of 20 is favourable, although the extreme values are not wanted. As a consequence, non-linear relations between the traits could arise. Graphical inspection of the relationships between descriptive traits did not reveal any deviation from linearity.

The general traits movement, conformation and free-jumping are scored on a subjective scale of 40 (very bad) to 100 (excellent) with an increment of 1.
The subjective traits conformation and movement have been scored since 1992, other traits have been scored since 1998.
The dataset contained scores on 36,159 horses in combination with information about their sex, place and date of classification, classifier, pedigree, percentage of thoroughbred and age. The dataset covered the recording period from 1992 to 2002, but traits introduced after 1992 included fewer observations (Table 1).
Inspection on jumping traits was not compulsory and the owner of the horse decided participation.

In order to account for heterogeneous variation among classifiers and years, the descriptive scores were standardised to a standard deviation of 4 points within classifier and year-groups. The general traits were standardised to a standard deviation of 6 points within classifier and year-groups.

The sport competition data included highest levels from lifetime performance in sport (Huizinga and Van der Meij, 1989). These lifetime totals, consisting of a character and number combination, were transformed to values on a linear scale. A square-root transformation was applied to accomplish a more normally distributed error term (Huizinga and Van der Meij, 1989). Competition results of 33,459 horses that participated in dressage and 30,474 horses that participated in show jumping during the years 1981 - 2002 were available. The horses ranged in age from 4 to 15 years. The competition dataset is very similar to the dataset analysed in a previous study (Ducro et al., 2002).

Table 1. Description of the traits of the linear scoring system of KWPN

Trait	score 1	score 40
Walk (n=36,110)		
- Correctness	toed in	toed out
- Stride	long	short
- Elasticity[1)]	supple	stiff
Trot (n=36,110)		
- Stride	long	short
- Elasticity	supple	stiff
- Impulsion	powerful	weak
- Carriage[2)]	carrying	on forehand
Canter (n=12,804; scored since 1998)		
- Stride	long	short
- Impulsion	powerful	weak
- Carriage	carrying	on forehand
Free-Jumping (n=8,378; scored since 1998)		
- Take-off: direction	upwards	forwards
- Take-off: speed	fast	slow
- Technique: foreleg	bent	stretched
- Technique: back	rounded	hollow
- Technique: haunches	open	tight
- Scope	much	little
- Elasticity	supple	stiff
- Care	careful	reckless

The three subjective traits conformation (n = 33,197), movement (n = 33,251) and jumping (n = 8,809) are scored from 40 to 100 with 100 being the best score.
[1)] The trait carriage of walk has not been scored anymore after 1995
[2)] The trait carriage of trot was introduced in 1996 (n = 21,499)

Genetic parameters of the traits recorded at the studbook entrance were estimated using the following model:

$Y_{ijklm} = \mu + \text{classifier}_i + \text{year}_j + \text{place/date}_k + \text{age/sex}_l + \text{animal}_m + e_{ijklm}$

where, Y_{ijklm} is the observed score for each subjective and descriptive trait for the mth animal (walk-stride,…, care); μ is the population mean; classifier_i is the fixed effect of the ith classifier (i= 1,…,25), j is the fixed effect of the jth year, place/date_k is the fixed effect of the kth combination of place and date (k = 1,…,1117) of the animal tested; age/sex_l is the fixed effect of the lth combination of age and sex (mares, stallions) (l=1..14); animal_m is the random effect of the mth animal ~ N(0, $\mathbf{A}\sigma^2_a$); and e_{ijklm} is the random ~N(0, $\mathbf{I}\sigma^2_e$) residual term.

Adjustment for percentage thoroughbred was conducted by including genetic groups in the pedigree structure.

If a horse had been classified more than once, only the first observation was taken. All records with missing values for either their place/date , age/sex pedigree or percentage of thoroughbred were deleted. Only horses in the age of 2-13 years were included. Classifiers having less than 50 observations were deleted. All geldings were assumed to have had the sex of stallion at the time of classification.

Genetic parameters of the competition data were estimated using the following model (Ducro et al., 2002):

$Y_{ij} = \mu + \text{age/sex}_i + \text{animal}_j + e_{ij}$

where, Y_{ij} is the observed competition performance on the j^{th} animal (dressage, show jumping); μ is the population mean; age/sex_i is the fixed effect of the i^{th} combination of age (4 yr.,…, ≥ 10 yr.) and sex (stallions, mares, geldings); animal_k is the random effect of the j^{th} animal (dressage j = 1,…, 31 268; show jumping j = 1,…, 28 597); e_{ij} is the random residual term.

The genetic parameters were estimated using the ASReml software package (Gilmour et al.,2002). Estimated heritabilities were derived from univariate analysis. Genetic and phenotypic correlations among the traits were estimated in bivariate analysis using starting values for the variances from the univariate analyses. The pedigree of each individual was traced back three generations. After univariate analyses of dressage and show-jumping, their genetic correlations with studbook-entry traits were estimated. These correlations were estimated in bivariate analyses with an unequal design including one studbook-entry and one competition trait (show-jumping or dressage).

RESULTS

Heritabilities. The estimated heritabilities of the traits of studbook entrance are shown in table 2. For. The estimates ranged from 0.19 (carriage of canter) to 0.32 (care of free-jumping and stride of trot) for most of the linear traits. Slightly higher was the heritability for scope of free-jumping, while the estimates for stride and elasticity of walk felt beneath this range. In trot and canter, stride happened to give highest estimates. The estimates within a gait were close to each other; around 0.28 for trot and around 0.20 for canter.
The subjective traits conformation and movement showed similar heritability estimates of 0.33 and 0.34 respectively, and the estimate for free-jumping was 0.40.

Table 2. Mean and standard deviation (sd) and heritability estimate (h²) of the linear descriptive traits and the subjective traits of the studbook entrance.

Traits	mean	sd	h²
Walk			
Correctness	19.6	3.9	0.25
Stride	19.6	4.0	0.16
Elasticity	20.2	4.0	0.15
Trot			
Carriage	21.8	4.1	0.28
Impulsion	21.9	4.1	0.27
Stride	20.1	4.0	0.32
Elasticity	21.1	4.1	0.29
Canter			
Stride	20.7	4.0	0.25
Impulsion	21.1	3.9	0.20
Carriage	22.1	4.0	0.19
Free-Jumping			
Take-off: direction	21.3	4.0	0.30
Take-off: speed	20.3	4.0	0.22
Technique: foreleg	20.6	4.0	0.22
Technique: back	21.3	4.0	0.31
Technique: haunches	21.3	4.0	0.27
Scope	20.4	4.0	0.37
Elasticity	21.9	4.0	0.24
Care	19.6	4.0	0.32
Subjective Traits			
Conformation	67.5	6.2	0.33
Movement	66.9	6.1	0.34
Jumping	62.2	5.9	0.40

The s.e.'s of the heritability estimates range from 0.02 to 0.04.

Genetic correlations

The genetic correlations of the descriptive traits of movement with the general traits are presented in table 3. The correctness of walk approved to be poorly related to any of the other traits of the studbook entrance. All other descriptive traits regarding gaits were favourably correlated to each other (results not shown). This was also true, though to a lesser extent, for canter.

Table 3. Genetic correlations of descriptive traits of movement with the general traits

	Walk			Trot				Canter		
	corr[1)]	stride	elast[2)]	carry[3]	impls[4)]	stride	elast[2)]	carry[3)]	impls[4)]	stride
Conformation	0.04	-0.63	-0.77	-0.76	-0.73	-0.71	-0.78	-0.75	-0.64	-0.68
Movement	0.06	-0.67	-0.82	-0.96	-0.96	-0.93	-0.97	-0.85	-0.77	-0.72
Jumping	0.02	0.09	-0.01	0.10	-0.05	0.07	0.00	-0.16	-0.39	-0.23

[1)]=correctness, [2)] = elasticity, [3)] = carrying, [4)] = impulsion

Except for correctness of walk, descriptive traits related to movement had a favourable genetic correlation (higher than -0.63) to the subjective traits movement and conformation. In particular the descriptive traits of trot were highly correlated to movement. The genetic correlations of the descriptive traits of trot and walk to jumping were close to zero. In contrast, the canter traits showed favourable genetic correlations with the free-jumping traits.

Table 4: Genetic correlations of free-jumping traits with general traits

	take off		technique					
	scope	speed	haunches	foreleg	back	impulsion	elasticity	care
Conformation	-0.04	0.01	-0.07	-0.09	-0.17	-0.09	-0.23	-0.13
Movement	0.02	0.00	-0.04	0.01	-0.07	-0.04	-0.21	-0.01
Jumping	-0.92	-0.73	-0.91	-0.84	-0.77	-0.92	-0.84	-0.93

The genetic correlations of the descriptive traits of free-jumping with the general traits are presented in table 4. The descriptive traits regarding free-jumping were favourably correlated to each other (results not shown). The free-jumping traits showed low correlations with the general traits conformation and movement; most of them were close to zero. Elasticity of free-jumping was an exception, since the genetic correlations to conformation and movement were –0.23 and –0.21, respectively. The genetic correlations of the free-jumping traits to the subjective trait jumping were high to very high correlated.

Table 5: Genetic correlations between the general traits of the studbook entrance

	conformation	movement	jumping
Conformation	--	0.82	0.13
Movement		--	0.02

Table 5 shows the genetic correlations among the subjectively scored traits of the studbook entrance. The traits movement and conformation were positively correlated to each other, while their correlations to jumping were low (conformation) or close to zero (movement)

From table 6 it can be seen that the genetic correlations of the gait traits to performance in dressage were highly favourable, ranging from –0.40 for impulsion of canter to –0.67 for elasticity of trot. Exception to this was the genetic correlation of the correctness of walk to dressage. The linear traits of the gaits were also favourable correlated to performance in show-jumping, of which the correlations of the canter traits were moderate and the correlation of the other gaits were low.
The genetic correlations of the linear free-jumping traits with performance in show-jumping were very highly favourable; all estimates were above 0.52 and four traits had estimates of 0.80 and above. The genetic correlations of the free-jumping traits with performance in dressage were moderate but unfavourable in most cases.

Table 6. Genetic correlations of descriptive and subjective traits of studbook entrance with dressage and show-jumping in competition

	Dressage	Show-Jumping
Walk		
- Correctness	-0.05	-0.06
- Stride	-0.53	-0.04
- Elasticity	-0.50	-0.14
Trot		
- Stride	-0.65	-0.11
- Elasticity	-0.67	-0.13
- Impulsion	-0.59	-0.11
- Carriage	-0.65	-0.14
Canter		
- Stride	-0.49	-0.33
- Impulsion	-0.40	-0.43
- Carriage	-0.50	-0.28
Free-Jumping		
- Take-off: direction	0.34	-0.88
- Take-off: speed	0.27	-0.53
- Technique: foreleg	0.20	-0.67
- Technique: back	0.19	-0.52
- Technique: haunches	0.27	-0.80
- Scope	0.30	-0.82
- Elasticity	0.09	-0.64
- Care	0.29	-0.80
Subjective Traits		
- Conformation	0.67	0.29
- Movement	0.69	0.23
- Jumping	-0.24	0.87

The s.e.'s of the genetic correlations range from 0.04 -0.11 for dressage and from 0.04-0.09 for show-jumping.

The subjective traits conformation and movement showed highly favourable correlations to performance in dressage and moderate favourable correlations to performance in show-jumping. The subjective trait free-jumping is highly favourable correlated to show-jumping, but moderately unfavourably correlated to results in dressage.

DISCUSSION

The aim of the study was to estimate the heritabilities of the movement and free-jumping traits of the studbook entrance and their genetic correlations to performance in dressage and show jumping competition. When the genetic parameters of these traits are suffciently high, then information of the studbook entrance could be used in the breeding program.
Estimated heritabilities were moderate to high. The heritabilities on the descriptive traits of walk and trot were slightly higher than estimated by Koenen et al. (1995) on partly the same dataset. Ducro et al. (2002) estimated heritabilities on similar traits from the First Stallion Inspection (FSI), a one-day field test for stallions. The estimates from the current study were slightly lower, but still in good agreement with the results of that study. The higher values of the FSI could be

due to a lower environmental variance in the traits, since the FSI test is conducted at one location and by one team of judges. Higher estimates at the FSI might also be caused by an upward bias, because the structure allows for a higher influence of judging on pedigree.
When comparing the descriptive traits to the traits recorded at young horse tests (Thorén et al., 2005), the heritability estimates from the studbook entrance are generally at the lower side of the range. Wallin et al. (2003) studied field performance tests for mares and their analysis resulted in the same estimation for conformation. Their estimate for gaits was lower than the estimate for movement in the current study and was accompanied by a lower estimate for canter and trot. Free-jumping in this study showed a much higher heritability than when jumping is under saddle in the field performance test (Wallin et al., 2003) or in competition. The influence of training and rider is probably causing the disturbance and can not be corrected for

The subjective traits conformation and movement showed high favourable correlations to performance in dressage and moderately high to performance in show-jumping. The latter is mainly due to the positive contribution of the canter traits, since trot and walk had low correlations to show-jumping. The genetic correlations of walk and trot to performance in dressage are in good agreement to the estimates of Wallin (2003), except for correctness of walk. Correctness of walk, although rather heritable, apparently has no functionality in sport performance. The correlations estimated by Koenen et al. (1995) were much lower, very likely because their evaluation was too shortly after introduction of the linear scoring system.

The subjective trait free-jumping and the liner traits of jumping had high to very high favourable genetic correlations to show-jumping, but unfavourable genetic correlations to dressage in competition. In contrast, all correlations of the descriptive traits related to gaits with performance in show-jumping were not unfavourable. Correlations between gaits recorded at performance tests and show-jumping varied from negative (Huizinga et al., 1990) or zero to positive (Wallin et al., 2003). Perhaps an unfavourable genetic correlation between jumping and dressage can not be seen when traits are inspected under rider. Then the horse is already specifically trained in dressage or jumping performance.

Because of their heritabilities and genetic correlations, a selection of the traits recorded at studbook-entrance is appropriate for predicting performance in dressage and show-jumping. Apart from the genetic parameters of the traits recorded at studbook entrance inspection, their suitability for using in breeding value estimation is due to large number of horses participating in this inspection. As a consequence the influence of preselection on the breeding values is lower compared to performance tests. Additionally, these inspections are cheaper than performance tests. Data from studbook entries can not entirely replace information from performance tests, because important aspects of horses like character, willingness to learn and endurance can be achieved from these tests.

CONCLUSIONS

The descriptive and subjective traits recorded at studbook entrance had moderate to high heritabilities. The genetic correlations of gaits to performance in dressage were highly favourable. Gaits were also favourably correlated to show-jumping, though to a lower extent. The jumping traits recorded at studbook entrance were highly favourable correlated to show-jumping, but unfavourably correlated to performance in dressage.
The current genetic evaluation for sport performance is based on performance data only. Inclusion of a selection of the traits recorded at studbook entrance is expected to increase the

quality of the genetic evaluation procedures and eventually to result in improved selection responses.

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