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Review article

# Review of genetic parameters estimated at stallion and young horse performance tests and their correlations with later results in dressage and show-jumping competition

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## Abstract

Results from performance tests and competitions of young horses are used by major European warmblood horse breeding associations for genetic evaluations. The aim of this review was to compare genetic parameters for various tests of young horses to assess their efficiency in selection for dressage and show-jumping. Improved understanding of genetic information across countries is also necessary, as foreign trade with semen is rapidly increasing. The review is based on inquiries to European breed associations and on (17) scientific publications available, which have analysed genetic parameters of young horse data and/or relationships between young and mature horse results in sport.

Despite differences in testing methods of young horses, results for major horse populations were in good agreement. Specially designed young horse performance tests, including that stallion tests, showed high heritabilities and high genetic correlations with later competition results. We recommend that test results are encouraged to be used across countries for genetic evaluation of imported stallions and semen. Short station tests are generally preferred when selecting stallions for both dressage and jumping traits, whereas competition data may be used when selecting for only one discipline. We also recommend that extensive field testing of young horses is encouraged and should include both genders.

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## 1. Introduction

Most warmblood horse breeders aim to breed horses that can perform in dressage or show-jumping

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competitions. Throughout Europe, different forms of testing sport horse stallions and young sport horses are practised (Bruns et al., 2001). The stallion performance tests are used as a tool for early selection of prospective breeding stallions. Ordinary young horse tests serve several purposes. One of the most important is to provide data for genetic evaluation of young horses as well as their parents, primarily by applying the BLUP animal model. Another important purpose is to use these tests as a means to find talented horses for the sport. To achieve genetic progress, both heritabilities of the traits recorded at tests or competitions and the selection intensity have to be reasonably high. Since results at advanced levels of competition are emphasised in the breeding goal for most sport horse breeds (Koenen et al., 2004), it is also important that tests at young age show highly positive genetic correlations with later competition results.

This review aims to compare genetic parameters for various tests of young horses, including stallions, in some leading European warmblood horse breeding associations as a preparatory work for improved assessment of breeding values of stallions across

countries. Another aim is to provide information that will indicate ways to improve the efficiency of different designs of tests or competitions for genetic evaluation and selection purposes.

## 2. Performance testing of sport horses in Europe

In performance testing of sport horses many similarities exist between European breeding organisations. In most countries the testing capacities at stations are used to test stallions of 3 to 4 years of age for at least 70 days. Exceptions are Great Britain, Hungary and Sweden, where the tests include no more than 8 days counting all repetitions (Table 1). In addition to the stallion performance tests (SPT), some breed organisations arrange station tests for mares, lasting between 14 and 50 days. The breed organisations of the Belgian, Finnish and Norwegian warmblood and Selle Français do not provide testing capacities at stations; instead they use field tests (FPT) and/or competition results (Bruns et al., 2001). The field performance test, in most countries, is a 1-day test used to test young mares and/or geldings.

Table 1

Young horse testing procedures that are included in the genetic evaluation in internationally important sport horse producing countries in Europe

Country	Belgium	Denmark	France	Germany	Ireland	The Netherlands	Sweden
Test method	C <sup>a</sup>	F S	C <sup>a</sup>	F S C <sup>a</sup>	S <sup>b</sup> C	F S	F
Age at test (years)	4–7	3–4 <sup>c</sup>	4–6	3–4 <sup>c</sup>	3–5 <sup>d</sup>	3–4 <sup>c</sup>	3–5
Sex	M G St	M G St	M G St	M <sup>a,c</sup> G <sup>a</sup> St <sup>a</sup>	M St	M St	M G St
Length of test (days)	365 <sup>a</sup>	1–70	365 <sup>a</sup>	1–100	1–365 <sup>c</sup>	1–70	1
Traits tested							
Conformation		F		F		F	F
Gaits		F S		F S	C S	F S	F
Performance							
Dressage		F S	C	F S C	C	S	F
(Show-)jumping	C	F S	C	F S C	C S	S	F
Eventing ability			C		C		
Behaviour		S		S	S		F
Health					S		F
No. of horses tested/year	1000	700	3600	3600 <sup>f</sup>	475	3400	1300
No. of foals registered/year	4000	2500	8000	26,700	4800	12,000	3000
Prop. Of horses tested/year %	25	28	45	13	10	28	43

Field test (F), station test (S), competition (C), mares (M), geldings (G), stallions (St).

<sup>a</sup> Yearly series of competition by age-class used for selection purposes.

<sup>b</sup> Station test for Irish Draught Horse stallions only.

<sup>c</sup> Most horses are tested at 3–4 years of age and to a lesser extent at older ages at field and station tests.

<sup>d</sup> Average age at performance.

<sup>e</sup> One day for mares, competition during at least 1 year for stallions.

<sup>f</sup> No. of horses tested in competition not included.

Table 2  
Summary of stallions' performance tests

Country	No. of stallions tested/year		Age at test (years)	Length of test (days)
	At station	In field/competition		
Belgium	–	30	4–7	1
Denmark	20	–	3	30–70
Finland	–	15	3–6	1–5
France	–	230/700	4–6	Field test: 1 CC: 365 <sup>a</sup>
Germany	300	–	3–4	30–100
Hungary	36	–	Unknown	8
Ireland	5	70	3–5	At station: 84 In competition: 1 year <sup>b</sup>
Netherlands	80	–	3	70
Sweden	40	20	3–5	8
United Kingdom	40	–	4.5	2 <sup>c</sup>

<sup>a</sup> Yearly series of competition by age-class, "Cycle Classique".

<sup>b</sup> Minimum of 1 year: Stallions must accumulate a minimum of 30 show-jumping points or the equivalent in dressage or eventing to complete performance test at competition.

<sup>c</sup> The test lasts 2 days for 3 consecutive years.

Generally gaits, jumping ability and rideability are judged at the FPT and station tests, and sometimes also conformation. Finally, most organisations use competitions as an additional test for young stallions, mares and geldings. Examples of such competitions are the "Cycle Classique" (CC) in France and Belgium, which include series of competitions where young horses, including stallions, compete in age-classes. In these two countries results from the CC constitute the main criteria for selection of stallions. An overview of the testing schemes used for genetic evaluation in important sport horse producing countries is presented in Table 1. The proportion of

young horses tested varies between 13% and 45% of registered foals in these countries.

Stallions entering test at station are normally trained by their owners or by professional riders and are preselected due to criteria related to conformation, gaits and jumping. In general, the test is considered a prerequisite for breeding whereby the requirements are defined in absolute or relative terms. Variables recorded during the test describe the basic gaits, rideability, jumping and behaviour through scores from 1 to 10 given by external judges and sometimes also by the trainer. The means of the variables are between 6 and 7. Standard deviations vary from 0.7 to

Table 3  
Heritabilities for traits recorded at station tests

Test trait	I	II	III	IV	V	VI	VII	VIII	IX	X	Mean value
Walk	0.73		0.32	0.20	0.25	0.43	0.34	0.34	0.46	0.45	0.39
Trot	0.65		0.28	0.23	0.37	0.50	0.45	0.51	0.37	0.34	0.41
Canter	0.54		0.25	0.54	0.33	0.47	0.36	0.42	0.39	0.28	0.40
Free jumping	0.30		0.71	0.70	0.42		0.47	0.39	0.47	0.55	0.50
Jumping	0.31		0.35	0.32	0.38	0.47	0.38	0.33	0.32	0.50	0.37
Rideability	0.64		0.46	0.56	0.30	0.52	0.44	0.41			0.48
Cross-country manner	0.41		0.15		0.15		0.20				0.23
Character	0.52										0.52
Dressage ability		0.35									0.35
Jumping ability		0.39									0.39

I–II Dutch studies, III–VIII German studies, IX–X Swedish studies. I: Huizinga et al. (1991a), II: Van Veldhuizen (1997), III: Jaitner and Reinhardt (1993), IV: Uphaus et al. (1994)—mare tests, V: Schade (1996), VI: von Velsen-Zerweck (1998), VII: Brockmann (1998), VIII: Lührs-Behnke et al. (2002), IX: Gerber Olsson et al. (2000), X: Gelinder et al. (2001).

1.7 (Bruns et al., 2001). A summary of the stallions' performance tests is given in Table 2.

### 3. Genetic parameters for tests at young age

#### 3.1. Station performance tests

Genetic parameters based on station performance test data have been estimated in several Dutch, German and Swedish studies (Tables 3 and 4). Most studies deal with station performance tests for stallions. The exception is the study by Uphaus et al. (1994), which is based on results from station testing of mares.

In the Netherlands, stallions are tested at station for 70 days, mainly at the age of 3. Earlier the station performance test lasted for 100 days. Huizinga et al. (1991a) estimated heritabilities and genetic correlations for the longer test and found the heritabilities to be high for gaits, character and rideability (0.54–0.73) and intermediate for cross-country and jumping (0.30–0.41). Genetic correlations were moderate to high between all analysed traits except between gaits and jumping (0.05–0.22). Based on the moderate to

high heritabilities and high genetic correlations with later performance at various stages during the test, it was concluded that testing periods could be shortened. Van Veldhuizen (1997) considered ability for dressage and show jumping when estimating heritabilities for the Dutch 70-day stallion performance test. The heritabilities were 0.35 for dressage and 0.37 for jumping. There are also station performance tests for 3-year-old mares in the Netherlands. This test lasts 35 days. Van Veldhuizen (1997) estimated the heritabilities for dressage and jumping ability for this test to be 0.36 and 0.54, respectively.

In Germany, Jaitner and Reinhardt (1993) estimated heritabilities for stallion performance test results from two test stations using a repeatability model. For gaits, jumping and rideability, the mean values of estimated heritabilities were 0.28, 0.68 and 0.40, respectively. Uphaus et al. (1994) compared field performance tests with station performance tests for Hanoverian mares tested at 26 stations. Mean heritabilities for the station performance test were similar to those of Jaitner and Reinhardt (1993); gaits 0.32, jumping 0.52 and rideability 0.36. Schade (1996) used data from station performance tests of Hanoverian stallions. Mean

Table 4  
Genetic correlations between traits recorded at station performance tests of stallions

Traits		I	II	III	IV	V	Mean value
Walk	Trot	0.92	0.75	0.78	0.75	0.40	0.72
	Canter	0.88	0.74	0.75	0.74	0.30	0.68
	Rideability	0.97	0.79	0.72	0.67		0.79
	Jumping	0.20	–0.20	0.03	0.03	0.21	0.05
	Free jumping	0.05	–0.24	–0.06	–0.15	0.27	–0.03
	Character	0.47	0.21	0.30			0.33
Trot	Canter	0.93	0.87	0.74	0.85	0.71	0.82
	Rideability	0.95	0.84	0.80	0.84		0.86
	Jumping	0.10	–0.15	0.12	0.03	0.29	0.08
	Free jumping	0.07	–0.19	–0.02	–0.06	0.14	–0.06
	Character	0.24	0.33	0.53			0.37
Canter	Rideability	0.94	0.80	0.76	0.83		0.83
	Jumping	0.22	0.05	0.30	0.33	0.54	0.29
	Free jumping	0.13	–0.05	0.19	0.19	0.40	0.17
	Character	0.36	0.27	0.37			0.33
Rideability	Jumping	0.18	–0.02	0.21	0.21		0.15
	Free jumping	0.05	–0.10	0.06	0.04		0.01
	Character	0.42	0.39	0.67			0.79
Jumping	Free jumping	0.92	0.92	0.96	0.94	0.93	0.93
	Character	0.77	0.00	0.18			0.32
Free jumping	Character	0.58	–0.20	0.11			0.16

I: Dutch study, II–IV: German studies, V: Swedish study. I: Huizinga et al. (1991a), II: Schade (1996), III: Brockmann (1998), IV: Lührs-Behnke et al. (2002), V: Gerber Olsson et al. (2000).

heritabilities for gaits, jumping and rideability were estimated at 0.38, 0.46 and 0.29, respectively. Velsen-Zerweck (1998) and Brockmann (1998) used data from the eight German test stations for stallions between 1986 and 1995 in multivariate analyses. The estimated heritabilities of von Velsen-Zerweck (1998) were slightly higher than those estimated by Schade (1996), 0.47, 0.47 and 0.52, respectively. Mean heritabilities estimated by Brockmann (1998) were in the same range, 0.41, 0.49 and 0.43, respectively. Finally Lührs-Behnke et al. (2002) used data from all stallions tested in Germany between 1986 and 2001 using a multiple-trait animal model. The heritabilities were estimated to be 0.42 and 0.41 for gaits and rideability, respectively, and to 0.36 for jumping. Genetic correlations between walk, trot and canter and between gaits and rideability varied from 0.67 to 0.87, as estimated by Schade (1996), Brockmann (1998) and Lührs-Behnke et al. (2002). The genetic correlations within test are in close agreement between these three studies except for the genetic correlations between gaits and jumping. Schade (1996) found almost consistently negative genetic correlations between gaits and jumping,  $-0.24$  to  $0.05$ , whereas Brockmann (1998) found genetic correlations from  $-0.06$  to  $0.30$ . Lührs-Behnke et al. (2002) estimated the genetic correlations between gaits and jumping from  $-0.15$  to  $0.33$ . In all three studies walk was the gait that was least genetically related to jumping and canter the most related.

In two Swedish studies, Gerber Olsson et al. (2000) and Gelinder et al. (2001) estimated heritabilities and correlations from the performance test for 4- to 5-year-old stallions, which lasts 8 days. The first study

included results from 1979 to 1993 and the second from 1979 to 1999. Heritabilities for gaits ranged from 0.28 to 0.46 and for jumping from 0.32 to 0.55. The genetic correlations between traits within test was estimated by Gerber Olsson et al. (2000) and ranged from 0.30 to 0.71 between gaits and was 0.93 between jumping traits. Like Huizinga et al. (1991a), they found no negative genetic correlations between the different gaits and jumping ( $0.14$ – $0.54$ ).

To sum up, literature estimates of heritabilities for station performance tests are moderate to high, on average  $0.4$ – $0.5$ , and reasonably similar except for Huizinga et al. (1991a). Genetic correlations between gaits and between gaits and rideability are high or very high, around  $0.8$ , with few exceptions. Free jumping and jumping seem to be very closely related traits because the genetic correlations are all higher than  $0.90$  between these traits. The most evident disagreement concerns the genetic correlations between gaits, or dressage-related traits, and jumping. These estimates range from  $-0.24$  (Schade, 1996, walk-free jumping) to  $0.54$  (Gerber Olsson et al., 2000 canter-jumping). In all studies, however, jumping (under rider) tends to be more correlated than free jumping to dressage-related traits, and canter is the single gait that is most positively correlated to jumping.

### 3.2. Field performance tests

At field performance tests, horses are shown at hand and/or ridden, most often by their own rider. Rideability is judged by a test rider and/or judge on the ground. Jumping ability can be tested by free jumping or jumping under rider or both. As for station

Table 5  
Heritabilities for traits recorded at field performance tests

Trait	I	II	III	IV	V	VI	VIIa	VIIb	Mean value
Walk	0.22		0.37	0.26	0.27	0.27	0.35	0.39	0.30
Trot	0.14		0.50	0.30	0.36	0.36	0.41	0.38	0.35
Canter	0.18		0.25	0.25	0.29	0.35	0.35	0.32	0.28
Rideability	0.03			0.21–0.27	0.24–0.29	0.30			0.21
Jumping	0.15		0.46–0.62	0.27–0.30	0.20–0.49	0.37	0.25–0.35	0.21	0.37
Balance			0.37						
Character	0.06								
Dressage ability		0.36							
Jumping ability		0.54							

I–II: Dutch studies, IV–VI: German studies, VIIa–b: Swedish study. I: Huizinga et al. (1990), II: Van Veldhuizen (1997), III: Ducro et al. (2002), IV: Uphaus et al. (1994), V: Schade (1996), VI: Brockmann (1998), VIIa: Gelinder et al. (2002), 3-year-olds, VIIb: Gelinder et al. (2002), 4-year-olds.

performance tests, genetic parameters based on field performance test data were estimated by Dutch, German and Swedish researchers. Estimates of heritabilities from the literature are shown in Table 5 and genetic correlations within test in Table 6.

In the Netherlands, field performance tests of young mares and geldings are held annually. The horses are shown ridden. Huizinga et al. (1990) estimated the genetic parameters for the Dutch test, as it was designed until 1990. Only the results of mares tested between 1983 and 1987 were used. The heritabilities were mainly low, 0.03–0.22. The genetic correlations were moderate to high, 0.34 (walk–jumping ability) to 0.91 (character–total score), except for the correlation between trot and jumping ability, which was very low (0.07). Ducro et al. (2002)

Table 6  
Genetic correlations between traits recorded at field performance tests

Traits		I	II	III
Walk	Trot	0.62	0.86	0.50
	Canter	0.67	0.70	0.58
	Rideability	0.67		0.65
	Balance		0.79	
	Jumping	0.34		
	Free jumping		–0.43 <sup>a</sup>	–0.14
	Character	0.87		
	Total score	0.88		
Trot	Canter	0.44	0.75	0.80
	Rideability	0.72		0.86
	Balance		0.88	
	Jumping	0.07		
	Free jumping		–0.31 <sup>a</sup>	–0.01
	Character	0.42		
Canter	Total score	0.66		
	Rideability	0.49		0.72
	Balance		0.94	
	Jumping	0.67		
	Free jumping		0.12 <sup>a</sup>	0.05
	Character	0.76		
Rideability	Total score	0.87		
	Jumping	0.50		
	Free jumping			–0.04
	Character	0.77		
Jumping	Total score	0.81		
	Character	0.58		
	Total score	0.66		
Free jumping	Balance		0.06 <sup>a</sup>	

I–II: Dutch studies, III: German study. I: Huizinga et al. (1990), II: Ducro et al. (2002), III: Schade (1996).

<sup>a</sup> There are three “jumping-traits” measured in this test: take-off, technique and power. This correlation is an average of these three.

estimated the genetic parameters for scores recorded at the Dutch “First Stallion Inspection”, a 1-day field test, pre-selective to the licensing stationary stallion performance test of 70 days. The material used was collected 1994–1999. Heritabilities were moderate to high (0.25–0.50) for gaits and “balance”, and high for jumping traits (0.46–0.62). Genetic correlations within test were high between gaits and very high between jumping traits, but negative between gaits and jumping, except for canter, which showed positive but low correlations to jumping traits.

In Germany, several studies have been performed on data provided by the Hanoverian “Zuchstutenprüfung” (broodmare test). Performance tests for Hanoverian mares can be either 1-day field tests or station tests. The mares can be tested from the age of 3 and onwards. At the field performance test the mares are shown by their own rider and by a test rider. Jumping ability is tested both by free jumping and jumping under own rider. In the study by Uphaus et al. (1994) most heritabilities for the field performance test were estimated to be moderate (0.2–0.3). The genetic correlations between traits within test varied between –0.09 and 0.89. Schade (1996) estimated genetic parameters for traits scored at the same test as Uphaus et al. (1994) but for mares tested between 1987 and 1993, i.e. additionally 3 years. Heritabilities varied between 0.27 and 0.42. The genetic correlations within test were high (0.50 to 0.86) except for those between free jumping and all other traits, which were negative or close to zero (–0.14 to 0.05). Brockmann (1998) used results from six different German breed organisations when estimating heritabilities for mare field performance tests. Heritabilities ranged from 0.27 to 0.37.

In Sweden, Gelinder et al. (2002) estimated heritabilities both for traits judged at the Swedish riding horse quality test (RHQT) for 4-year-old horses and a performance test for 3-year-old horses. Both are 1-day field tests. At the RHQT horses are shown both by hand and ridden by their own rider. The horse owner chooses whether the horse is tested in free jumping or jumping under rider. The 3-year-old horses are shown by hand and in free jumping. The test also includes an optional rideability test. For both tests heritabilities were moderate, 0.21–0.41.

Estimates of heritabilities for the field performance tests in the literature are quite homogeneous, about 0.3 for all traits judged. Exceptions are found in the study

of Huizinga et al. (1990) where the heritabilities were somewhat lower than in the other studies. For the genetic correlations between dressage-related traits and jumping traits there is a certain disagreement between studies. Schade (1996) and Ducro et al. (2002) showed negative or very low correlations. Huizinga et al. (1991a), on the other hand, showed low to moderately positive genetic correlations between dressage-related traits and jumping traits. All three studies seem to agree, however, that canter is the individual gait that is the most correlated to jumping ability.

### 3.3. Young horse competitions

Another way of testing the young horse is through competitions where the horses participate in different age classes. Generally, all genders are allowed to participate. Most horses compete in either dressage or jumping. Genetic parameters based on data from such competitions were estimated in French, Belgian and German studies. Results are summarised in Table 7.

In France and Belgium, the genetic evaluations are based on competition. The so-called “Cycle Classique” (CC) is organised for horses between 4 and 6 years in France and between 4 and 7 years in Belgium. The results are included in the genetic evaluations. All genders are allowed to participate and the mean number of starts/horse is usually about 10. Only a few percent of the horses compete in dressage or eventing; thus show-jumping is the dominating discipline. Tavernier (1992) estimated the heritabilities for the French young horse competitions in jumping to 0.33 for 4-year-olds, 0.28 for 5-year-olds and 0.22 for 6-year-olds. The genetic correlations

between the results of two consecutive years were higher than 0.90 and between the results at 4 and 6 years it was 0.76 (Tavernier, 1992). Performance was measured by the logarithm of annual earnings. Because stallions are selected on basis of CC, the parameters are valid for stallion selection as well. In Belgium, Janssens et al. (1997) estimated the heritability of results from single events in the CC. When including all complete records, they found a heritability of 0.10 and a repeatability of 0.27. The average number of performances was 7.4 per horse and year, which gives a heritability close to 0.27 for annual performance.

Lührs-Behnke et al. (2002) estimated heritabilities for competitions for young inexperienced horses in Germany. The trait used was transformed rank, which was the square root of placing. Dressage competition ranks for young horses showed a heritability of 0.12 and show-jumping ranks 0.11.

## 4. Genetic correlations between stallion performance tests, young horse tests and competition results

When choosing test traits for genetic evaluation purposes it is important that the traits tested are highly correlated to later competition results, own or relatives, since results at advanced levels of competition are the primary goal trait for most sport horse breeds (Koenen et al., 2004). It is also important to choose adequate variables when evaluating the competition results. Variables recorded at performance tests vary only little between breed organisations (Bruns et al., 2001), but more regarding competition results (Ricard, 1998). Results may, e.g. be obtained at different ages and levels of sport. In most of the internationally important sport horse producing countries, studies have investigated the correlations between young horse tests and competition results of the mature horse. An overview of genetic correlations between test traits recorded at station performance tests, young horse tests or young horse age-class competitions and competition results for experienced horses is given in Table 8.

In Germany, Schade (1996) estimated high genetic correlations between stallion performance tests at station and competition results in dressage and

Table 7  
Heritabilities for traits recorded at age-class competitions for young horses

Trait	I	II <sup>a</sup>	III <sup>a</sup>
Cycle Classique, 4 years	0.33		
Cycle Classique, 5 years	0.28		
Cycle Classique, 6 years	0.22		
Cycle Classique Belgium, 4–7 years		0.10	
Young horse competition dressage			0.12
Young horse competition show-jumping			0.11

I: French study: Tavernier (1992).

II: Belgian study: Janssens et al. (1997).

III: German study: Lührs-Behnke et al. (2002).

<sup>a</sup> Heritabilities for single events.

Table 8

Genetic correlations between test traits recorded at stallion performance tests, young horse tests or young horse competitions and later competition results

Trait in performance test	Competition trait (transformed by Log or square root)			
	Earnings/placing	Cumulative points	Highest level in competition	Annual earnings
<i>Dressage</i>				
Walk		0.20 <sup>d</sup> , 0.49 <sup>c</sup>	0.05 <sup>f</sup>	
Trot		0.57 <sup>d</sup> , 0.73 <sup>c</sup>	0.27 <sup>f</sup>	
Canter		0.26 <sup>d</sup> , 0.73 <sup>c</sup>	0.36 <sup>f</sup>	
Gaits		0.72 <sup>e</sup>		
Temperament gaits		0.75 <sup>e</sup>		
Rideability	0.88 <sup>a</sup> , 0.86 <sup>b</sup> , 0.68 <sup>c</sup>		0.83 <sup>f</sup>	
Character			0.60 <sup>f</sup>	
Dressage ability			0.68 <sup>g</sup>	
Total score			0.41 <sup>f</sup>	
<i>Show jumping</i>				
Free jumping	0.64 <sup>c</sup>	0.75 <sup>d</sup>		
Jumping under rider		0.87 <sup>d</sup>		
Jumping ability	0.79 <sup>a</sup> , 0.78 <sup>b</sup>	0.88 <sup>e</sup>	0.48 <sup>f</sup> , 0.90 <sup>g</sup>	
Temperament jumping		0.93 <sup>e</sup>		
Total score			0.05 <sup>f</sup>	
Young horse competition, 4 years				0.67 <sup>h</sup>
Young horse competition, 5 years				0.85 <sup>h</sup>
Young horse competition, 6 years				0.85 <sup>h</sup>

German studies: <sup>a</sup>Schade (1996) (stallion performance test/competition), <sup>b</sup>Bruns and Schade (1998) (stallion performance test and mare performance test/competition), <sup>c</sup>Brockmann (1998) (mares FTP/competition).

Swedish studies: <sup>d</sup>Gelinder et al. (2001) (stallion performance test/competition), <sup>e</sup>Wallin et al. (2003) (RHQT/competition).

Dutch studies: <sup>f</sup>Huizinga et al. (1990) (mares FPT/competition), <sup>g</sup>Van Veldhuizen (1997) (stallion performance test and mare performance test/competition).

French study: <sup>h</sup>Tavernier (1992) (young horse competition/competition at 10 years).

show-jumping. Competition results (prize money/placing) were transformed using a 10-log. The analysed genetic correlations were between rideability at stallion performance test and competition results in dressage (CRD) (0.88), and between jumping at stallion performance test and competition results in show jumping (CRJ) (0.79). Bruns and Schade (1998) found high genetic correlations between rideability scored at stallion performance test at station as well as between field performance test for mares and performance at dressage competitions (0.86 and 0.86). For jumping the estimates were slightly lower (0.78 and 0.78). Further, Brockmann (1998) estimated the genetic correlations between mares field performance test and competition results, also using prize money/placing transformed with 10-log. The traits used from the field performance test were rideability and free jumping. For dressage the genetic correlation was 0.68 and for jumping 0.64.

In Sweden, Gelinder et al. (2001) used cumulative placings and cumulative points, transformed with 10-log, when estimating the correlations between the Swedish stallion performance test and competition results. Almost identical results on genetic correlations were obtained with both measurements, being moderate to high and ranging from 0.20 (walk) to 0.57 (trot) between different gaits at stallion performance test and CRD. Further, the genetic correlations between jumping at stallion performance test and CRJ were high and ranged from 0.75 (free jumping) to 0.87 (jumping under rider). Wallin et al. (2003) used the same methods as Gelinder et al. (2001), i.e. 10-log transformations of cumulative placings and cumulative points, to estimate the correlations between field tests of 4-year-olds and lifetime performance in dressage and show jumping. Also here cumulative placings and points gave same results on genetic correlations with CRD. The genetic correlations

between gaits and CRD were high, ranging from 0.49 to 0.75. For jumping traits the correlations were even higher, ranging from 0.88 to 0.93.

In the Netherlands, Van Veldhuizen (1997) estimated the genetic correlations between station performance data for Dutch mares and stallions and competition data of their half-sibs and offspring, using a square root transformation of highest level in sport accomplished during the lifetime of the horse. High correlations were found both between dressage ability at station performance test and CRD (0.68) and between jumping ability at station performance test and CRJ (0.90). Ducro et al. (2002) studied the genetic relations between the so-called first stallion inspection (FSI) in Holland and competition results at mature age. The genetic correlations between gaits and balance at FSI and CRD were moderate to high (0.37–0.72). Very high genetic correlations were found between jumping-related traits and CRJ (0.81–0.92).

In France, Tavernier (1992) also found high genetic correlations between jumping performance at young horse competitions (CC) and competitions at mature age (10 years). Between performance at 4 years and mature age the correlation was 0.67. Between 5 and 6 years and mature age the correlations were 0.85.

## 5. Discussion

Performance testing of stallions and young horses plays a major role in genetic evaluations in most countries producing sport horses, especially when the breeding objective includes both dressage and jumping. For specialised breeding objectives, e.g. jumping in France, Ireland and Belgium, competitions for young horses play the same role.

### 5.1. Heritabilities

For both stallion performance tests and young horse tests heritabilities for gaits are moderate to high with few exceptions. The stallion performance tests show slightly higher heritabilities (~0.4) for gaits than the young horse field tests, notably even compared with the station performance tests for young horses (~0.3). Heritabilities for jumping related traits are moderate to high for the stallion performance tests (0.4–0.5), and moderate for young horse field per-

formance tests (0.2–0.4). Free jumping generally shows a higher heritability than jumping under rider, on average 0.50 compared with 0.37. The higher heritabilities for station test of stallions may be due to more careful judging by experienced judges. The heritabilities are similar within groups (stallions/young horses) regardless of length of testing period. This suggests that it might be possible to shorten the performance tests without losing any valuable information as suggested by Huizinga et al. (1991b). The results by Gerber Olsson et al. (2000) suggest even much shorter test periods because their results are in the same range as the German results, even though the stallions were tested for a much shorter period (8 days). For stallions, short but repeated tests could possibly be the most effective in the future.

In sport horse breeding the overall goal trait is the success in competition across all levels which can be measured objectively. Low heritabilities are found for competition results in several studies when using the measure for each event. Nevertheless the accuracy has shown to be acceptable through repeated performances and fairly good repeatability (Ricard, 1998; Gelinder et al., 2001; Aldridge et al., 2000; Foran et al., 1995; Tavernier, 1990).

The French and Belgian studies of results from age-class competitions in jumping yielded heritabilities in the range 0.2–0.3. Clearly, competition data show results of a similar order as 1-day field performance tests, but lower heritabilities than data obtained from station performance tests designed for testing and selection of stallions, 0.37–0.50 (Table 3).

### 5.2. Genetic correlations between traits

The genetic correlations within tests are generally high between dressage-related tests such as gaits and rideability as well as between jumping traits. The genetic correlation between free jumping and jumping under rider was on average 0.93. For the genetic correlations between dressage-related traits and jumping traits there is a certain disagreement between studies. The German studies, Brockmann (1998) and Schade (1996) reported similar negative or very low correlations. The Dutch study (Huizinga et al., 1991a) and the Swedish study (Gerber Olsson et al., 2000) on the other hand, showed low to moderately positive genetic correlations between dressage-related traits

and jumping traits. All studies seem to agree, however, that canter is the individual gait that is the most correlated to jumping ability, whereas the other gaits are scarcely correlated with jumping traits. For studies of genetic correlation between dressage or dressage-related traits (gaits) and jumping it is important that all horses have the same opportunity to be tested for both trait categories. This requirement is only fulfilled in young horse performance test data (including stallion performance tests). Competition data are from selected horses with results usually only from one discipline, and would thus yield biased results.

### 5.3. Genetic correlations between young age test results and later competition results

High correlations with later competition results have been shown for the Dutch, German and Swedish stallion performance tests (0.7–0.9). Similar values were found for the French “Cycle Classique” in jumping. However, the correlation for the 4-year-olds was lower (0.67) than those from station tests of stallions of the same age (0.8–0.9) and discipline.

Brockmann (1998) indicated that testing stallions over 30 days at station is genetically equivalent to testing young horses in field performance tests. Studies by Friemel (2001) indicated even increased genetic progress by shortening the testing period and early use of performance-selected stallions. The high genetic correlations found for the Swedish test not only support further shortening of the testing period, but also draw the attention to the age of testing. Clearly testing stallions aged 4–5 years allows a more demanding test than aged 3 years.

### 5.4. Testing system—factors affecting genetic progress

The younger we can test the horses with a satisfying heritability, the earlier we can predict the breeding value of the stallions and get a shorter generation interval. As indicated by Gelinder et al. (2002) the test does not have to be that complicated to reveal the talents of the young horse. The easier it is to show the horse, the more people may bring their horses to testing. This will also lead to higher selection intensity, provided that breeders select the best performing horses for breeding.

Most breeding associations test only young mares. To increase accuracy in prediction of breeding values more horses should be tested. Thus, breeding associations should also allow young geldings and non-approved stallions to participate. Allowing both sexes of horses doubles the testing capacity compared to just mare tests.

Field-testing of young horses seems to have many advantages for several breed organisations with multi-trait breeding goals, such as the Danish Warmblood, most German breed organisations, the Dutch Warmblood Association and the Swedish Warmblood Association. The tests used by these organisations are often well established and accepted among breeders and horse-owners. The heritabilities are similar to those estimated for station tests of mares, but lower than those at the more thorough station tests of stallions. Many horses can be tested, which gives a high accuracy of the sires’ predicted breeding value. By testing the young horses’ talents for both dressage and jumping it is also possible to obtain a more complete picture of the sires’ breeding values at an early stage. Hence, traits tested must be well defined and the testing procedure standardised. Further, it is important that judges are experienced in the sport and well prepared for their task to ensure that horses are assessed in as standardized manner as possible, wherever they are shown. This could be achieved with co-ordinated training of judges, both nationally and internationally, aimed at achieving more similar testing schemes between breed organisations and facilitating international evaluations.

Some breed organisations, such as the Selle Français, the Belgian stud-books and the Irish sport horse, have traditionally based their genetic evaluation mainly on young horse competitions (Aldridge et al., 2000; Janssens et al., 1997; Tavernier, 1990). This system is satisfactory as long as the breeding goal is focused on one discipline since most horses only compete in one discipline. However, it must be noted that the heritabilities are generally lower than results obtained at station performance tests of stallions.

In conclusion the various performance test results (station performance test, field performance test and age-class competition for young inexperienced horses) have proved to be clearly heritable with highest results for station tests of stallions, and highly genetically correlated with the goal traits. On condi-

tion that a sufficiently large proportion of the foals born are tested as young horses, it is possible to achieve earlier results. Performance testing of young horses enables a faster genetic progress than evaluations based solely on competition results of older, experienced horses. As mentioned before, horses usually only compete in one discipline, which gives an incomplete picture of a stallion's inheritance if competition results are used as the sole source of information and the organisation has multi-purpose breeding objectives. Moreover the mature horse is naturally more influenced by rider and training than the young horses. The risk of bias is reduced when integrating all data, i.e. combining data from competitions, stallion performance tests and young horse tests, as has been done in Germany during 2002 (Bruns, 2002; Jaitner and Reinhardt, 2002; Lührs-Behnke et al., 2002; Koerhuis and van der Werf, 1994). Provided a large proportion of competition horses also have performance test results as young horses, the multi-trait evaluation will account for the selection of horses for competition. Thus, it is important to increase the proportion of young horses tested, as well as to further develop multi-trait models for genetic evaluations based on both performance tests at young age and competition data.

## 6. Conclusions

- Specially designed young horse performance tests, including stallion tests, show moderate to high heritabilities and clearly high genetic correlations with later competition results.
- Station performance tests of stallions show somewhat higher heritabilities than 1-day field performance tests.
- Heritabilities of competition data from age-class competitions in jumping are in the same range as 1-day field performance tests. Correlations with later competition results were high, but somewhat lower for 4-year-olds than for 5- and 6-year-olds.
- Station performance tests of stallions can be conducted in considerably shorter test periods than usually have been practised without compromising the ability to detect the inherited traits.
- Field tests of young horses are more efficient for genetic evaluations than station tests due to the

greater testing capacity and lower costs for each tested horse. Such field tests of young horses should include all genders to increase the capacity of stallion progeny testing and seeking talents for the sport.

- With extensive performance testing of young horses it could be possible to achieve earlier and more accurate results, thereby enabling a faster genetic progress than with evaluations based merely on competition results for older, experienced horses.
- The system with genetic evaluations based principally on competitions can be satisfactory for populations that have a breeding goal focused mainly on one discipline, provided many young horses participate in competitions.
- The fact that horses usually only compete in one discipline, although their population of origin is aimed for dual purposes, means that an incomplete and biased picture may be obtained of a stallion's breeding value if competition results are used as the sole source of information.
- The risk of selection bias when using competition data for genetic evaluations in dual-purpose populations should be reduced when integrating data from both performance tests and competitions for young and mature horses.
- All procedures for testing young stallions (long and short station tests and age-class competitions) reviewed in this study, comprising leading European equine sports populations, show reasonable accuracy in predicting breeding values of young stallions. This fact suggests that European warmblood breeding organisations should accept testing results across countries when grading and licensing stallions.

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