Multi-trait Evaluation of Swedish Warmblood Stallions at Station Performance Tests including Field and Competition Records

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Licentiate thesis
Swedish University of Agricultural Sciences
Uppsala 2006

Institutionen för husdjursgenetik

Rapport 144
Publication No. 144

Swedish University of Agricultural Sciences
Department of Animal Breeding and Genetics

Uppsala 2006
ISSN 1401-7520
ISRN SLU-HGEN-R--144--SE

ISBN 91-576-7178-8

Omslagsteckning: Ebba Olsson
Tryck: SLU Service/Repro, Uppsala 2006

Abstract

Olsson, E. 2006. Multi-trait Evaluation of Swedish Warmblood Stallions at Station Performance Tests including Field and Competition Records. Licentiate Thesis.
ISBN 91-576-7178-8

The aim of this thesis was to estimate genetic parameters for stallion performance test (SPT) results and their correlations with riding horse quality tests (RHQTs) as well as competition results in show jumping and dressage. The thesis also investigates the possibility of increasing the accuracy in selection of Swedish Warmblood stallions by combining their performance results with information about performance of related horses RHQTs and competitions in show jumping and dressage.

Data were collected from records covering the 801 stallions used in the analyses. Data on approximately 14 900 horses with RHQT results, 26 800 horses with results in show jumping and 14 200 horses with results in dressage competitions were also analysed. Mixed model analyses using Restricted Maximum Likelihood were applied for estimation of genetic parameters.

Estimated heritabilities were 0.38–0.42 for individual gaits under rider and 0.23–0.65 for jumping traits in SPT. Heritabilities for competition traits were 0.17 for dressage and 0.27 for show jumping. The heritabilities for traits recorded in the RHQT varied between 0.19 and 0.36. Genetic correlations between all jumping traits assessed at the SPT were very high and positive, varying between 0.87 and unity. Jumping-related traits judged in the SPT have positive and high genetic correlations with show jumping results in competitions (0.78–0.96). Gaits judged in the SPT and results in dressage competitions had somewhat lower genetic correlations (0.44–0.77). The genetic correlation between conformation and results in dressage competitions was 0.22. Genetic correlations between jumping recorded in the SPT and jumping recorded in the RHQT were 0.72–1.00, whereas gait correlations were 0.90–1.00. Overall, the results suggest that the traits measured in the SPT are reliable indicators of competition performance.

The accuracy of the SPT rises considerably when if information on performance of relatives in competitions in show jumping and dressage, and in the RHQT are used simultaneously. For the breeding goal trait ‘show jumping’ the mean accuracy rose from 0.60 to 0.68 for stallions born in Sweden, an increase of 13%. For stallions born outside Sweden, the corresponding figure was 5%. With the goal trait ‘dressage’ information from the RHQT and competition results in dressage improved the accuracy from 0.41 to 0.55 for stallions born in Sweden, an increase with 39%. For imported stallions the improvement was 11%. Thus, it is important to consider pedigree information in genetic evaluations of stallions in performance tests.

Keywords: Riding horses; Performance; Animal model; Correlations; Breeding values

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Appendix

Papers included in the thesis

I. Gerber Olsson, E., Árnason, Th., Näsholm, A. and Philipsson, J. 2000. Genetic parameters for traits at performance test of stallions and correlations with traits at progeny tests in Swedish Warmblood horses. *Livest. Prod. Sci. 65, 81-89.*

II. Olsson, E., Näsholm, A., Strandberg, E. and Philipsson, J. 2006. Use of field records and competition results in genetic evaluation of on station performance tested Swedish Warmblood stallions. *Livest. Sci.* Submitted for publication.

Paper I and Paper II are reproduced in this thesis by kind permission of the journals concerned.

Introduction

In Sweden about 5 000 Warmblood mares are covered each year, which corresponds to about 5% of the European Warmblood population (Philipsson, 2005). This is a small number of mares compared with, for example, the breeding area Hannover, Germany, where about 12 000 mares are covered every year, and the Netherlands, where there are over 14 000 brood mares (WBFSH, 2006). Despite its relatively small Warmblood population, Sweden has had great international success at European, World Cup and Olympic level during the last decade, primarily with Swedish bred horses or stallions active in Swedish breeding (Philipsson, 2005).

The breeding goal for the Swedish warmblood horse is "to produce a noble, correct and durable riding horse which through its temperament, rideability, good movements and/or jumping ability is internationally competitive" (ASVH, 2006). The main breeding objectives are good competition results in dressage and show jumping. A second priority is that of producing horses for leisure purposes. Although secondary, this is important in Sweden, where riding is one of the most common sport activities among young people.

More than 200 warmblood stallions are used annually used for breeding in Sweden. In a quarter of cases semen from these is shipped from other countries, primarily Germany. Artificial insemination is the most common breeding method (85%) (Philipsson, 2005). The majority of stallions in Sweden are approved after having a stallion performance test (SPT). Others are approved following good competition results, or on the basis on excellent results in SPT in a country other than Sweden. About 50% of all stallions undergoing SPT are imported from other countries.

During the last few decades Sweden has made considerable genetic progress in dressage and, in particular, show jumping (Philipsson, 2005). The reason for this is most likely to be efficient use of SPT and well attended progeny tests at 3 (young horse test) and 4 years old (riding horse quality test) (Gelinder *et al.*, 2002). Since 2005 breeding value estimates have been based on the riding horse quality test (RHQT), young horse test (YHT) and competition results. BLUP-indexes are regularly published on the internet (ASVH, 2006). This system of genetic evaluation in horses makes it possible for breeders to select mares for breeding; it also provides an efficient tool for early progeny testing of stallions. Altogether this allows the Swedish Warmblood Breed (SWB) to continue to make genetic progress in both show jumping and dressage.

The main breeding objective for the SWB – *i.e.* improved competition results in advanced level dressage and show jumping – may be a conflict with the desire to keep generation intervals short. Good competition results at higher levels can be expected, realistically, at age of 10–13 years. Putting stallions and mares into breeding at this age will slow down genetic progress both because the long generation intervals will be too long and because there will be too small a number

of stallions and mares to select among. The most important part of the breeding program is the selection of stallions, and a successful horse–breeding programme must have a sustainable, efficient test for stallions at the earliest age possible. In France and Belgium competition results achieved at low age (4–6 years) are used for the single trait goal 'show jumping'. However, most other European countries select for dual purpose performance at 3–5 years of age in specially designed performance tests (Thorén Hellsten *et al.*, 2006). The tests also have to reflect talents in both dressage and show jumping. Today most of the warmblood stallions in Sweden are approved on the basis of results gained in the SPT at 4–5 years of age. Some are approved having done well in competitions when they are older. Approximately 30–50 three-five-year-old stallions per year participate in the Swedish SPT. Of these about 30% are approved for breeding. Gelinder *et al.* (2001) estimated in a preliminary study that the genetic correlations between jumping traits in SPT and show jumping at competitions were higher (0.74 to 0.88) than correlations between gaits in SPT and dressage at competitions (0.20 to 0.66). Given the great importance of the SPT in securing the genetic advance in the SWB, it is of interest to see how the reliability of the SPT can be improved. It is also important to study how results from the SPT correlates with the offspring test results used in genetic evaluations.

Aim of the thesis

The overall aim was to investigate the possibilities to increase the accuracy in the selection of Swedish Warmblood stallions by combining their performance results with information from relatives participating in the RHQT and competitions in show jumping and dressage. As a basis the aim of the thesis was to estimate genetic parameters for stallion performance test results and to estimate genetic correlations between stallion performance test results and riding horse quality tests as well as competition results in show jumping and dressage.

Summary of the investigations presented

Materials

In both papers, data from SPT were provided by the Swedish Warmblood Association. In Paper I, SPT results from 1979-1993 were included; the data related to 378 stallions with observations from 683 tests. In Paper II, SPT results from 1979-2005 were included; the data here related to 801 stallions. In Paper I repeated observations were included. By contrast, in Paper II only the last observation per stallion and trait was used. The analysed traits included: individual gaits, the temperament and general appearance of the horse in the gaits test, free jumping, temperament and general appearance in free jumping, jumping under

rider, temperament and general appearance in jumping under rider, and conformation (only in Paper II).

Data from the RHQT were obtained from the Swedish Horse Board and the Swedish Warmblood Association. In Paper I data from 1973-1993 were included and in Paper II data from 1973-2005. In Paper I the data from the RHQT related only to offspring off stallions that had participated in the SPT. The offspring had participated in the RHQT from 1983 to 1993. In Paper II all information, 1973–2005, was used. The traits included in the analyses were gaits, jumping and conformation.

Results from competitions in show jumping and dressage were analysed in Paper II. Results from the 1970s to 2004 were available. During this period approximately 27 000 horses had participated in show jumping competitions: the corresponding figure for dressage there was approximately 14 000 horses.

In Paper I the pedigree file carried information on from the stallion's sire and maternal grandsire. In Paper II it carried information on at maximum 72 000 horses and the pedigree for each individual was, when possible, traced back seven generations. Among the performance-tested stallions, 93% had complete pedigree information for at least four generations.

The trait 'conformation' was differently defined in the two papers. In Paper I all available information on conformation was included and the information related to five scores: type, head-neck-body, legs, walk at hand and trot at hand. In Paper II conformation included only the scores for type and head-neck-body. Today these two scores are included in the breeding value estimation.

Methods

In Paper I, genetic and phenotypic parameters were estimated by use of restricted maximum likelihood in the DMU-package of Jensen and Madsen (1994). An animal model was applied. The derivative free REML programme devised by Meyer (1993) was used to estimate (co)variances between the SPT and the RHQT.

In Paper II genetic and environmental parameters were estimated using the average information algorithm (Jensen *et al.*, 1997) for restricted maximum likelihood included in the DMU-package of Jensen and Madsen (1994). Standard errors of heritabilities and genetic correlations were obtained by Taylor series expansions (Madsen and Jensen, 2000). Again, in Paper II animal models were used. The DMU-package was used also for the prediction of BLUP breeding values.

Main findings

Heritabilities

The heritability estimates from Paper I and II are summarised in Table 1. The heritabilities for gaits, varying between 0.37 and 0.46, were similar in the two papers. For free jumping, and for temperament and general appearance in free jumping the heritabilities were in the same range (0.23–0.55), but they were higher and involved smaller standard errors in Paper II. The heritabilities for jumping under rider, and for temperament and general appearance in jumping under rider differed most between the papers. Heritability for jumping under rider was 0.32 in Paper I and 0.65 in Paper II. The corresponding figures for temperament and for general appearance in jumping under rider were 0.33 and 0.51. The difference in material could be one explanation for the variable heritabilities. In Paper II results from SPT were recorded over a period that is twelve years longer than the corresponding period in Paper I and with more than twice as many stallions. Thus, the heritabilities are more accurately estimated.

Table 1. *Summary of estimates of heritabilities with standard errors as subscripts for traits recorded at stallion performance tests in Paper I and II*

	Heritability	
Trait in stallion performance test	Paper I	Paper II
Walk	$0.46_{0.13}$	$0.42_{0.09}$
Trot	$0.37_{0.11}$	$0.41_{0.09}$
Canter	$0.39_{0.11}$	$0.42_{0.10}$
Temp.[a] Gaits		$0.38_{0.11}$
Conformation		$0.25_{0.11}$
Free jumping	$0.47_{0.13}$	$0.55_{0.09}$
Temp.[a] Free jumping	$0.23_{0.14}$	$0.36_{0.11}$
Jumping under rider	$0.32_{0.14}$	$0.65_{0.11}$
Temp.[a] Jumping under rider	$0.33_{0.23}$	$0.51_{0.12}$

[a] Temp., Temperament and general appearance

Genetic correlations

Table 2 summaries the results relating to genetic correlation in both papers. Generally the genetic correlations between traits scored in the SPT analysed in Paper I and II were similar. Genetic correlations for gaits varied between 0.11 and 0.90. The genetic correlation between walk and canter was lower in Paper II (0.11) than it was estimated to be in Paper I (0.30). This could have been due to a difference in the two datasets, since in Paper I the data was collected through repeated observations, in Paper II only the last observation per stallion was used. Moreover, the models differs between the two papers, Paper I includes a permanent environmental effect as it included repeated observations.

Genetic correlations between the different jumping traits were, in general, higher (varied between 0.44 and unity) than those for gaits. Only two of the genetic correlations between the jumping traits scored in the SPT differed much in the two Papers. The genetic correlation between free jumping and temperament and general appearance in jumping under rider was higher in Paper II (0.87) than

it was in Paper I (0.44). The genetic correlation between temperament and general appearance in free jumping, and temperament and general appearance in jumping under rider, was also higher in Paper II (0.90) than it was in Paper I (0.50). This could again be explained by the smaller material in Paper I.

Table 2. *Summary of estimated genetic correlations for traits scored in stallion performance tests presented in Paper I and II. Standard errors as subscripts*

	Genetic correlation	
Trait in stallion performance test	Paper I	Paper II
Walk-Trot	$0.40_{0.08}$	$0.34_{0.13}$
Walk-Canter	$0.30_{0.06}$	$0.11_{0.17}$
Trot-Canter	$0.71_{0.16}$	$0.67_{0.07}$
Temp.[a] Gaits-Walk		$0.43_{0.15}$
Temp.[a] Gaits-Trot		$0.84_{0.07}$
Temp.[a] Gaits-Canter		$0.90_{0.08}$
Free jumping - Temp.[a] free jumping	$0.99_{0.03}$	$1.00_{0.03}$
Free jumping - Jumping under rider	$0.99_{0.23}$	$0.89_{0.10}$
Free jumping - Temp.[a] jumping under rider	$0.44_{0.14}$	$0.87_{0.12}$
Jumping under rider - Temp.[a] jumping under rider	$0.90_{0.06}$	$0.99_{0.02}$
Jumping under rider - Temp.[a] free jumping	$0.79_{0.19}$	$0.94_{0.12}$
Temp.[a] jumping under rider - Temp.[a] free jumping	$0.50_{0.26}$	$0.90_{0.14}$

[a] Temp., Temperament and general appearance

Most of similar traits recorded in the SPT and the RHQT were highly correlated. The exception was illustrated by the genetic correlation between conformation in RHQT and gaits in SPT, which differed substantially between the two papers: walk and trot by hand were included in the trait conformation in Paper I but not in Paper II (Table 3).

Table 3. *Summary of estimated genetic correlations between traits scored at stallion performance tests (SPT) and riding horse quality test (RHQT) with standard errors (S.E) as subscripts presented in Paper I and II. The conformation trait in Paper II is a mean of two scores and in Paper I it is a mean of five scores (and is therefore not the same trait)*

	Genetic correlation	
Trait	Paper I	Paper II
Jumping (RHQT)-Gaits (SPT)	0.26	
Jumping (RHQT)-Free jumping mean[a] (SPT)		$0.72_{0.11}$
Jumping (RHQT)-Jumping under rider mean[b] (SPT)		$0.69_{0.12}$
Jumping (RHQT)-Jumping mean[c] (SPT)	1.00	
Gaits (RHQT)-Gaits (SPT)	1.00	$0.91_{0.12}$
Gaits (RHQT)-Conformation (SPT)		$0.36_{0.12}$
Gaits (RHQT)-Jumping mean[c] (SPT)	0.35	
Conformation (RHQT)-Gaits (SPT)	0.75	$0.19_{0.13}$
Conformation (RHQT)-Jumping mean[c](SPT)	0.07	

[a] Mean for free jumping and temperament and general appearance for free jumping
[b] Mean for jumping under rider and temperament and general appearance for jumping under rider
[c] Mean for free jumping, temperament and general appearance for free jumping, jumping under rider and temperament and general appearance for jumping under rider

In Paper II genetic correlations between SPT, competition and RHQT traits were estimated. The genetic correlations here were estimated separately for jumping-related and dressage-related traits. All genetic correlations were positive. In the jumping-related traits they varied from 0.72–0.88, and in dressage-related traits, including conformation, they varied from 0.18–0.90.

Breeding values

In Paper II breeding values for jumping, dressage and conformation for stallions that have participated in the SPT were predicted using information from the SPT, the RHQT and competition results. The accuracy of the breeding values for stallions tested in the SPT in 2004 and 2005 was calculated. The results showed that accuracy increased when information from relatives that had taken part in the RHQT and competitions was used.

Stallions born outside Sweden offer less information about relatives participating in competitions and the RHQT. For stallions born in Sweden, accuracy rose from 0.60 to 0.68 for the breeding goal trait 'show jumping', an increase of 13%, when information from the RHQT and competitions in show jumping was used. For stallions born outside Sweden, accuracy rose from 0.57 to 0.60 for show jumping when all available information was used. This is an increase with 5%. For stallions born in Sweden, accuracy rose from 0.41 to 0.55, an increase with 34%, for dressage when the information incorporated results from the RHQT and competition results in dressage. The corresponding rise for imported stallions was from 0.38 to 0.42, an increase of 11%.

General discussion

Short tests are reliable

The heritabilities for free jumping, jumping under rider and gaits in Papers I and II (Table 1) were in the same(or almost the same) range as the corresponding heritabilities estimated by von Velsen-Zerweck (1998) and, Brockmann (1998) in Germany, and Ducro *et al.* (2002) in the Netherlands. In general the genetic correlations in both papers were in the same range as genetic correlations estimated by Lührs-Behnke (2002), Wallin *et al.* (2003) and van Veldhuizen (1997). This indicates that the Swedish SPT, which is performed during an eight-day period, is performed in a way that ensures its results correspond well with the much longer SPT operated in Germany and the Netherlands. The SPT in Sweden tests stallions at an greater age than those in Germany and the Netherlands. This may partly explain the excellent quality of the results delivered by much shorter and less costly test in Sweden. It is easier to see the quality of a stallion's performance at an age of 4–5 years, when he is more mature and capable as a sport horse, than it is at 3 years, which is the usual age for test abroad.

Increasing accuracy of results in the stallions performance test

The results in Paper II show that it is possible to increase accuracy considerably, when stallions are evaluated in the SPT, by using information from relatives' performance in competitions and the RHQT. For show jumping, accuracy can be increased by 13% for Swedish born stallions. For stallions born outside Sweden the corresponding increase was 5%. For the goal trait 'dressage', accuracy increased by 34% for Swedish-born stallions and with 11% stallions born outside Sweden. The larger effects for Swedish bred stallions depend on more complete information from RHQT and competitions for these stallions vs. the foreign bred stallions. The larger effect in genetic evaluation of dressage compared to show jumping depends on the lower correlations between the goal trait dressage and SPT and RHQT results, which both show relatively high heritabilities.

The current method of assessment in the SPT- *i.e.* giving all stallions a subjective score for pedigree and suitability for jumping and/or dressage according to the performance of ancestors in Sweden and abroad – is, according to the results in Paper II, a step in the right direction. However, if we consider information from relatives in the statistical analysis,- it is possible to arrive at a more accurate evaluation of stallions in the SPT. All stallions entering the SPT may be given a predicted breeding value that is based on information from relatives' performance in the SPT, the RHQT and competitions in Sweden. SPT judges can use this breeding value to give the stallions entering the SPT a score for pedigree and suitability for jumping and/or dressage. The number of stallions born outside Sweden taking part in the SPT has risen during the last few years. Imported stallions naturally come with less information about relatives' results in Sweden. With these stallions, predicted breeding values have to reflect both phenotypic results from relatives abroad and the subjective assessment of the judges. This helps to ensure that the stallions are not treated unfairly.

Stallions approved due to good competition results

During the last few years the number of stallions being approved for breeding on the basis of their competition results has increased. This may give rise to concern. We have an effective SPT in Sweden, and to achieve further genetic improvement we need to allow potential breeding stallions to participate in the SPT. The stallions are, at 3–5 years old, less affected by environmental factors. The are also younger, usually, than stallions that have competed when, if approved, they will be used for breeding. Stallions approved on the basis of good competition results are not tested in *both* show jumping and dressage, whereas stallions in the SPT are. The information from both disciplines that is available following the SPT is most likely to be of interest to breeders, because breeders, riders and trainers seek horses that are suitable for both jumping and dressage (Jönsson, 2006). It should, of course, be possible to obtain approval for breeding on the basis of good competition results. However, the question is what minimum level of result should be required – that is, what level will make it likely that the stallion is a 'population improvers' despite having missed the opportunity to qualify through SPT when younger. This should be an exception for some especially good competition stallions, not a general route of approval. Such a policy is justified as the

heritability of competition results are much lower than the SPT results, and that the genetic correlations between SPT and competition results are high.

Breeding objective and correlations between traits

Over recent years, there has been a debate in Sweden about the possibility of dividing the warmblood population into two subgroups, one selected for show jumping and one for dressage. A recently circulated questionnaire suggested that the majority of people active in the horse sector (as riders, trainers and breeders) were not interested in splitting the breeding goal in two. Rather, they wanted a show jumping horse with reasonably good gaits and conformation, or a nice looking dressage horse with good movements which can also jump although not at advanced levels (Jönsson, 2006). These results are in agreement with in the way in which the SPT has developed in Sweden. During the last few years, stallion owners have been able to choose whether they want the stallion to be tested as a talent for dressage or for show jumping after an all-round test for both disciplines. In this connection the finding in Paper I, that there are positive genetic correlations between gaits and jumping ability in SPT and RHQT (0.26–0.35). Thus it is quite realistic to select (since there is no genetic antagonising in such selection) for both improved gaits and jumping ability. The results in Paper I showed, however, that the positive correlations estimated within SPT exists primarily between canter and jumping (0.40–0.54). Correlations involving walk and trot are lower (0.14–0.27).

If the stallions are to be tested in both disciplines they also have to be trained in both disciplines. Only then can they be assessed fairly. However, it is likely that they will receive more thorough training in their best discipline than they do in the other. This is because it is essential for a stallion to show real superiority in at least one discipline if it is to be taken seriously by the breeders.

Another relationship that seems to be essential in the selection process is that between conformation and the two sport disciplines. In Paper II we showed that the genetic correlation between conformation in the SPT (type, head-neck-body) and competition results in dressage was 0.22. Wallin *et al.* (2003) estimated genetic correlations between conformation (type; head-neck-body; legs; walk at hand; trot at hand) in the RHQT and results in dressage competitions (accumulated lifetime upgrading point) to be 0.38 and between conformation in RHQT and show jumping to be 0.42. In the survey by Jönsson's (2006) it was concluded that good conformation of the horse was important for the trainers, breeders and riders. There is a rule in the SPT saying that it is possible to approve a stallion exceptionally talented only for one discipline even if the horse's conformation and/or results in the other discipline are insufficiently good. These stallions can, of course have a positive effect in breeding if they are mated with the right kinds of mares. However, in general, desirable stallions will have excellent capacity in both disciplines and good conformation – or more realistically, they will have at least an excellent capacity in one discipline, good capacity in the other, and good conformation. These characteristics are in line with what the breeders, riders and trainers want from the breeding system (Jönsson, 2006).

Temperament – the need for a mental test?

In Jönsson's survey (2006) it was also concluded that the temperament of the horse was one of the most important traits to consider in the breeding goal. The temperament should, according to the responses to the questionnaire, be different for horses with different areas of use. The difference in desired temperament between dressage and jumping was not as big as that between the competition horse and the pleasure horse or riding school horse. One question raised was whether temperament is tested enough in young horse tests and the SPT. The stallions obtain three different temperament and general appearance scores in the SPT: one for gaits, one for free jumping and one for jumping under rider. These scores take into account the way in which the stallions behave during the different tests. The three most important factors contributing to a high score are the willingness of the horse to cooperate with the rider, his willingness to work, and the absence of nervousness. Jönsson (2006) also showed these to be the most desireable properties of a 'good' temperament, when respondents were asked to define that. However, the question is whether this really is enough for selecting horses well suited to riding school activities. The answer is, probably not, because in the SPT hardly any effort is put into evaluating the stallion's stable temperament, how easy he is to handle, or how easily he is are frightened by novel objects appearing without notice. These things are, of course, of great interest to all people handling horses, in whatever situation, but they are especially important for riding schools and pleasure riders, because there the people handling the horses are often less experienced. Taking care of, and being with, the animal is for many horse people often just as important as riding; so safety, and 'cool' horses, are required.

So far, no country has applied special mental tests to assess the stallion's in an SPT. It is a challenge to compose a mental test that shows the horse's mental state without risk of injury or disturbance of performance-testing. Perhaps it is difficult to correctly judge stallion's temperament during the SPT. The stallions are young, often not used to being away from home, and stabled closely with unknown stallions. All these factors will make them more tense. It ought to be discussed whether these mental tests are better suited for incorporation into offspring tests, such as the RHQT or the YHT, that are run when the horse is 3 and 4 years old. It may be difficult to obtain acceptance for this among stallion owners, but it would certainly seem that breeders, riders and riding schools instructors want to have an extended mental test of stallions. Mental testing is something discussed among ordinary horse people. If breeders and buyers demand it, a system for the mental testing of stallions, or the offspring of approved stallions, will have to be developed. Of course, a mental test has to be evaluated properly before being used in routine evaluations.

Concluding remarks

- The traits tested in the SPT have moderate to high heritabilities and high genetic correlations with results in both dressage and (even more so) show jumping. This implies that the test is an efficient tool for selecting breeding stallions.
- Genetic correlation between jumping and temperament and general appearance in jumping assessed in the SPT is so strong that the two traits can be regarded as almost the same trait. This is true for both free jumping and jumping under rider.
- Genetic correlations between SPT and RHQT are high, and therefore similarly defined traits in the two different tests can be regarded as virtually the same genetic trait. This, is important for progeny test purposes.
- Accuracy in the SPT can be increased considerably when information about relatives' performance in show jumping and/or dressage, and in the RHQT, is used by applying a multi-trait BLUP-evaluation when predicting breeding values of stallions after the SPT. This system would, however, be more readily exploited in the evaluation of stallions born in Sweden, as these stallions have the most complete ancestor information.

Future research

It would be desirable to establish correlations between the well attended offspring test performed when a horse is 3 years old (YHT), introduced in 1999, and the SPT. The number of horses that have participated in the YHT is now sufficiently large to make this kind of analysis possible.

It would also be of interest to examine the effects of the subjective scoring of ancestor' performance in show jumping and/or dressage given by the judges in the SPT on the stallion's final SPT results. What effect, if any, does the former have on the latter?

In the coming years, it would be interesting to compare the two different ways of evaluating stallions in the SPT (the traditional method still used today, with a subjective score for ancestors' performance, and the method presented in Paper II, in which data from competitions and RHQT are added to the stallion's result in SPT) on a larger number of stallions than were examined in Paper II.

A large issue to be resolved is how to assess the temperament of stallions when selecting them for breeding. The stallion's temperament should, of course, be evaluated in a consistent way. A reliable suitably presented description of temperament is important to mare owners choosing breeding stallions. Special mental tests should be developed and compared with the presently practised ways

of judging temperament during the performance testing of stallions and their offspring in RHQT.

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Acknowledgements

The work leading to this thesis was carried out whitin the Department of Animal Breeding and Genetics, at the Swedish University of Agricultural Sciences. It was financially supported by the Swedish insurance company AGRIA. Thank you!

I am grateful to the Swedish Warmblood Association (ASVH), the Swedish Horse Board and the Swedish Equestrian Federation for providing the data.

So many people have supported me over the years which I have worked on this thesis, and I wish to express my gratitude to all of you. Special thanks to some of my colleagues, friends and family:

Jan Philipsson, för din aldrig sinande och smittande entusiasm, dina visioner gällande svensk ridhästavel, din förmåga att lära mig att omsätta siffror på genetiska parametrar till något spännande och viktigt praktiskt sett samt din förmåga att se de stora sammanhangen. Tack för många spännande arbetsuppgifter och ett gott handledarskap!

Anna Näsholm, för att du alltid har tagit dig tid att hjälpa mig, dina kloka råd som du levererat med en härlig distans till forskningsvärlden och ditt stöd när min forskning känts tung och seg.

Erling Strandberg, för alla kloka synpunkter och råd som du så lugnt och sakligt förmedlat, för många trevliga möten och givande samtal.

Thorvaldur Árnason för att du har gett mig inblick i avelsvärderingens grunder och för gott samarbete och handledarskap under arbetet med min första artikel.

Anki Roth, min allra bästa mailkompis, för att du har trott på min förmåga, lärt mig att ta de stora stenarna först, sporrat mig, gett mig råd och tips, fått mig att skratta, ställt de besvärliga frågorna samt fått mig att få distans till forskningen och inse vad som är viktigt i livet.

Åsa Viklund, Emma Thorén Hellsten, Åsa Braam för alla intressanta diskussioner och utbyten av erfarenheter gällande många olika saker som t ex identiteter, härstamningar, BLUP, resultat, modeller, SAS-program, undervisning, kurser, pedagogik och allt annat som kan röra häst.

Margareta Rundgren för att Du introducerade mig till vetenskapligt skrivsätt, fick min bild av hästen som djur att väsentligt nyanseras samt för alla intressanta och lärande diskussioner om hästar och pedagogik i samband med hästkurserna och hippologutbildningen.

Anna-Lena Holgersson för vänskap och intressanta diskussioner rörande de viktiga sakerna i livet.

Tack till *alla som arbetar på institutionen för husdjursgenetik* för att ni gör hgen till en så trevlig arbetsplats. Speciellt tack till *Siw Karlsson* och *Dan Englund* för snabb sekreterar- och datasupport.

Tack till *alla studenter* jag mött under åren i många olika sammanhang som har ställt kluriga frågor, som utvecklat min förmåga att förklara saker begripligt, inspirerat mig till att ta reda på mer om saker jag inte visste eller kunde, givit mig nya infallsvinklar samt varit en allmän inspirationskälla för min forskning.

Mina föräldrar, Lena och Peter, som stöttat mig att våga ta den jobbigare vägen, fått det att vara självklart med utbildning och fått mig att förstå vikten av att studera det man tycker är roligt – hästar!

Mina systrar Anna och Marie-Louise med familjer för att ni alltid finns och ställer upp när det behövs och för att ni tror på mig.

Min man Pontus familj som har berikat min värld och är en så viktig del av mitt och min familjs liv.

Min egen fina familj Pontus, Ebba, Beata och Caspar för att ni är det viktigaste i mitt liv och att varje dag med er blir något speciellt. Er kärlek är det bästa i mitt liv!