(Paper presented at 7th World Congress Applied to Livestock Production, Montpellier, August 2002)

TESTING AND GENETIC EVALUATION OF SPORT HORSES IN AN INTERNATIONAL PERSPECTIVE

E.P.C. Koenen[1] and L.I. Aldridge[2]

[1]NRS, PO Box 454, 6800 AL Arnhem, The Netherlands
[2]Irish Horse Board, Agriculture House (4E), Kildare Street, Dublin 2, Ireland

INTRODUCTION

The aim of many horse breeding organisations is to improve the genetic ability of warmblood riding horses for performance in sport competitions. Riding horses are used for many different equestrian disciplines including dressage, show jumping and eventing competitions all over the world. The 43 member organisations of the World Breeding Federation for Sport Horses (WBFSH) register approximately 130,000 foals annually, of which 80% are bred in Europe. Reflecting the trend in other livestock breeding areas there has been a dramatic increase in the use of artificial insemination in the sport horse industry over the past number of decades. While in the earlier days of horse breeding the use of natural mating largely restricted the exchange of genetic material across breeding programmes, breeders may now more easily use genetic material from other breeding programmes. As a result countries with large breeding populations such as Germany and France have become large exporters of fresh and chilled semen. This large exchange of genetic material across populations is reflected by the frequent representation of German and French sires in the pedigree of active breeding horses all over the world.

Breeders may use different sources of information such as performance test results, WBFSH rankings and/or estimated breeding values (EBVs) to make selection decisions. Without a thorough knowledge of the details of how each value is reached, breeders will have problems in making optimal selection decisions, especially when foreign information is considered. Unfortunately, detailed and easy to understand information is not readily available for practical breeders. This lack of transparent information may become more problematic with the further internationalisation of equestrianism.

To study the optimal use of information on sport horses for breeding the INTERSTALLION working group was established by the WBFSH, EAAP and ICAR organisations in 1998. The main aims of this group are (1) to review breeding objectives, testing and evaluation systems and (2) to explore ways of harmonising and comparing EBVs across countries. As a start, the INTERSTALLION working group analysed the answers to a questionnaire from 19 breeding organisations to review the present status of testing and genetic evaluation of warmblood sport horses. The aim of this paper is to present and discuss the results of this analysis.

BREEDING OBJECTIVES

Definitions of breeding objectives vary largely across organisations (Koenen and Aldridge 2001). The trait definitions given by many horse breeding organisations (such as a “a noble correct and beautiful horse”) clearly reflect the fact that many traits in horse breeding, in contrast to other livestock species, are not easy to measure and can only be defined in a subjective manner.

The main performance traits recorded by breeding organisations were show jumping, dressage and eventing, whereas driving is often of minor importance (Table 1). Some breeding organisations only mention the sport discipline, whereas other breeding organisations also specify the level of performance within the discipline (e.g. national and/or international competition).

The main non-performance traits recorded were conformation, gaits, behaviour, health (including soundness, durability and robustness) and fertility (Table 1). Conformation is the most important non-performance trait that is defined differently across organisations. Many breeding organisations mention aesthetic conformation (“noble”, “expressive”, “well-shaped”) as a breeding objective trait as it often affects the financial value of a horse. In addition, many breeding objectives also mention functional conformation as it is expected to relate to other breeding objective traits such as sport performance, longevity and health.

None of the defined breeding objectives included explicit information on the relative importance of individual traits, although in practice breeding organisations put different weightings on the traits recorded in the breeding objective. For example, the Holstein, Irish Sport Horse and Selle Français studbooks emphasised show jumping, whereas the Trakehner studbook emphasised dressage.

Table 1. Frequency of performance and non-performance traits recorded in the breeding objectives of 19 breeding organisations for warmblood sport horses

Performance traits	Frequency	Non-performance traits	Frequency
show jumping	15	conformation	15
dressage	13	gaits	12
eventing	10	behaviour	10
driving	4	health / fertility	9

TESTING SCHEMES

Performance traits. Breeding organisations mainly use three types of tests to record performance data: station performance tests, field performance tests and competition tests (Bruns *et al.* 2001).

A station performance test consists of young horses (3-4 years of age) being tested under uniform conditions. The testing period depends on the breeding organisation and the sex of the horse. In Germany and The Netherlands stallions are tested for 70-100 days, while their station tests for mares do not take more than four weeks. In some other countries (Sweden, Hungary and Great Britain) testing of all sexes does not take more than eight days including all repetitions. Gaits, rideability and jumping are commonly scored at station performance tests. The repeatability of these scores is generally high due to the very uniform testing conditions. In general, observations recorded at station performance tests for stallions have a high heritability (0.40-0.60) and a high genetic correlation (0.70-0.90) to competition data (Ricard *et al.* 2000). However, in practice the high costs largely restrict the proportion of horses that are tested at station. Although the relative number of tested horses is very small, these data are extremely relevant as good test results are often a prerequisite before stallions are approved for breeding.

One-day field performance tests with possible repetitions are used to test young stallions (e.g. in Belgium, Finland, France and Norway) or young mares. A large advantage of a field test is the relative large testing capacity. The relative number of horses tested in the field varies largely among organisations and may go up to 60% for young breeding mares of the Hanoverarian studbook (Bruns *et al.* 2001). Compared to station performance tests, observations from field performance tests usually have a lower accuracy due to a shorter test period and more bias due to pre-training by the horse owner. However, horses in field tests are less preselected than horses in station performance tests. Field test data have a lower heritability (0.10-0.30) and a lower genetic correlation with competition data (0.65) in comparison to station test data (Ricard *et al.* 2000).

Many breeding organisations record data from riding sport competitions that are open to all sexes. At these competitions, various variables including scores, earnings or placings for dressage, show jumping and eventing are recorded (Bruns *et al.* 2001). The advantage of competition data is the feasibility to record large amounts of data at relatively low cost. However, the main disadvantage of recording competition data is the relatively low repeatability. Heritability estimates for these observations often range from 0.10 to 0.30 (Ricard *et al.* 2000). Another disadvantage is the fact that competition data, especially at higher levels, can only be recorded late in life. Furthermore, horses starting in competition are highly preselected.

Non-performance traits. The majority of breeding horses are assessed for conformation at studbook entrance and/or during performance testing. The number and the definitions of the conformation traits scored in each organisation vary greatly. Conformation is generally either scored on a subjective (Christmann 1996) or on a linear scale (Koenen *et al.* 1995).

Only a very small proportion of horses are tested for health traits, as these tests are often limited to young stallions that are tested before or during station performance tests. At these tests, stallions can be tested for bone diseases, cryptorchidism, roaring and other genetic defects. In many situations, stallions are not accepted for breeding when they have unfavourable results in these tests. However, Sweden is unique in also including health traits in the field tests. In these Riding Horse Quality Tests about 35% of all four-year old horses are tested on orthopaedic and medical status (Wallin 2001).

Data recording on fertility is often restricted to semen quality tests for young stallions. However, in The Netherlands and Sweden foaling percentages of stallions are published.

Observations on behaviour include scores on character and temperament that are sometimes recorded during performance tests.

GENETIC EVALUATION

Genetic evaluations for sport horses presently include evaluations for show jumping (7 countries), dressage (5), conformation (5) and eventing (1) (Table 2).

For performance traits, genetic evaluations are based on various test results: Belgium, France and Ireland only use competition results, Denmark and Sweden only use performance test results, whereas Germany and the Netherlands combine competition and performance results.

The unadjusted performance data (ranks, scores and the highest level in competition) are often transformed to improve problems with non-linearity and non-normal distributions (Ricard 1988).

The main non-genetic effects in the statistical model are age and sex: performance results on average increase with age and stallions and geldings have on average a higher performance than mares. Some statistical models also adjust for the effects of location, rider and permanent environment. Several countries use more information sources simultaneously to evaluate sport performance traits. For example, in the Netherlands a bivariate animal model combines competitions results (highest level) and station performance results (score for riding ability) to estimate breeding values for performance in competition. The most extensive model is the German model which considers results from competition (4 traits), stallion performance tests (6) and mare performance tests (5) simultaneously.

Table 2. Genetic evaluation systems for performance and conformation traits of warmblood riding horses in seven countries

Country	Trait[A]	Observations	Reference
Belgium	J	ranks in competition	Janssens *et al.* 1997 Janssens and Vandepitte 2000
	C	ranks in shows	Janssens, *pers. com.*
Denmark	C, D, J	performance test results	Jensen *et al.* 1989
France	D, E, J	earnings in competition ranks in competition	Tavernier 1991 Ricard and Chanu 2001
Germany	D, J	ranks in competition test results	Von Velsen-Zerweck 1998 FN 2001
	C	scores	Christmann 1996
Ireland	J	ranks in competition	Reilly *et al.* 1998 Aldridge *et al.* 2000
Sweden	C, D, J	performance test results	Árnason 1987 Árnason *et al.* 2001
The Netherlands	D, J	highest level in competition test results	Huizinga and Van der Meij 1989 Koerhuis and Van der Werf 1994
	C	scores	Koenen *et al.* 1995

[A]C = conformation, D = dressage, E = eventing and J = show jumping.

Genetic evaluations for conformation are based on scores from studbook entrances (Germany, The Netherlands and Belgium) or from performance tests (Denmark and Sweden). Breeding values are often estimated for general traits such as type, legs and general impression. The Dutch genetic evaluation also includes EBVs for 26 linear conformation traits. To facilitate interpretation, EBVs are transformed to a relative scale with a mean of 100 and a standard deviation of 20 or 4 before publication. However, countries use different definitions for the genetic base population when transforming the EBVs to a suitable scale for publication: The Netherlands, Ireland and Belgium include all horses in the base population whereas other countries only include horses of a specific age and sex.
The EBVs are often estimated at yearly intervals in autumn or winter. The EBVs are published in magazines and/or on the Internet as single trait EBVs. Some countries such as Germany and Sweden also combine EBVs into an index (Árnason *et al.* 2001; FN 2001).

DISCUSSION AND FUTURE RESEARCH NEEDS

Although not all organisations provided detailed answers, this questionnaire is a first systematic comparison of the different methods for testing and genetic evaluation for sport horses. These results can be useful when trying to improve the selection efficiency in sport horse breeding. First, the publication of these results in a standardised format on the Internet (http://www.wbfsh.org) would be an easy and cheap method to provide breeders with information that may improve their understanding of the different breeding programmes. Secondly, these results can also be the basis on which to formulate future research needs, relating to breeding objectives, testing schemes and genetic evaluation systems.

Breeding objectives. Breeding objectives should provide breeders with clear information on all traits to be improved by genetic selection. The interpretation and comparability of present (subjective) breeding objectives will be improved when breeding organisations carefully consider the completeness and uniformity of the breeding objectives. The interpretation may be further improved when more information on the relative importance of individual traits is included.
Completeness and uniformity. The completeness of the breeding objective description can be improved by including the traits that are considered for selection by breeding organisation but that are not yet explicitly mentioned. As an example, the questionnaire showed that many breeders also select for health and fertility although these traits are not explicitly recorded in the breeding objective. In addition, breeding objectives will become more complete when traits are defined in more detail. For example, performance traits can be specified by mentioning both the discipline (show jumping, dressage and eventing) and the level of performance (national and international level). Defining the discipline of performance is very relevant as the low genetic correlations between individual disciplines (e.g. Huizinga and Van der Meij 1989; Ricard and Chanu 2001) show that genetic improvement in one performance discipline will hardly improve the performance in other disciplines simultaneously.
It is of practical relevance for breeding organisations to study carefully whether differences between breeding objectives represent different traits or if they are differences due only to wording. Even when the variation is not due to wording and traits seem to be identical, genetic studies of the traits recorded by different breeding organisations can reveal variation in the traits recorded.

Relative importance. In dairy cattle and pigs, the expected effect of genetic improvement on the economic efficiency (economic values) is often used to rank breeding animals (Hazel 1943). However, it questionable if the economic efficiency of horse production is a very good criterion for the derivation of relative weightings as many horse breeders manage breeding as a hobby with little or no requirements for profit (SLU 2001). Therefore, the desired gains approach (Brascamp 1984) may be a more suitable method to derive relative weightings for the traits recorded in horse breeding. When using this method, breeding organisations have to decide on the desired genetic levels of future generations which may include the future needs of the end-users as well as the market position of a breeding organisations (De Vries 1989). Additional studies on long-term developments in horse production and equestrian sport will assist breeding organisations in defining high-quality breeding objectives.

Testing schemes. Testing schemes should provide breeders with accurate and easy to understand test results on all traits of interest. Adequate information on the relationships between test results and breeding objectives, and on data quality and the optimal combination of different sources of information is not always easy available.

Relationship between test results and breeding objective. Although many breeding organisations want to select horses that can perform at the highest international level (e.g. Olympic Games, Nations Cups and World Championships) they only record competition results at the lower national levels. Estimates for the genetic parameters of international performance are needed to evaluate the suitability of observations at national level in order to select horses for performance at international level.

Although non-performance traits such as health, fertility, longevity and behaviour are often considered important (Philipsson *et al*. 1998), test results for these traits are scarce. Many health tests are expensive and test results are often only available to the horse owner. Observations on longevity of sport horses are generally not easily available as horse-owners and veterinarians do not record health data and culling reasons systematically.

As an alternative to direct selection, it may be attractive to use observations on related traits which can often be measured early in life at lower costs. For example, Wallin *et al.* (2001) showed that observations on conformation during performance tests can be used as a predictor of survival. Another example is the use of length of competitive life as a measure of longevity (Ricard and Fournet-Hanocq 1997).

Selection for health and fertility traits may further benefit from the developments in molecular genetics using marker assisted selection. However, before associations between genetic markers and genes affecting health traits can be studied, adequate phenotypic observations have to be available.

Data quality. The different data recording systems make an across country comparison of test results difficult. Therefore, the interpretation and comparability of the recorded data may improve when breeding organisations standardise these systems. Standardisation of data across countries may be easier for station and field tests than for competition data as competition data often depends on the national structures of the riding competitions.

With subjective scores, it is important that classifiers score and rank animals consistently (Bowden 1982). The introduction of (inter) national training sessions of classifiers and detailed statistical monitoring of subjectively scored observations will further improve the data quality.

Optimising testing capacities. Many different tests are available in sport horse breeding. The optimal use of multiple tests within a breeding programme depends on, amongst other things, the costs of data recording, repeatability of the observations and their genetic relationship to the breeding objective traits. For example, stallion selection is often a two-step procedure including station performance tests and competition tests. In practice, the use of both tests have to be optimised according to costs and expected genetic response. Earlier optimisation studies (Huizinga 1991; Bruns and Schade 1998; Von Velsen-Zerweck 1998) have already shown that the total genetic response of a breeding programme depends very much on how the available test results are combined.

Genetic evaluation. Due to the large variation in the methods of data recording and genetic evaluation, breeders cannot easily compare EBVs across organisations. However, with the increased exchange of genetic material, the need for a genetic evaluation across countries is highly desired. In dairy cattle, multi-trait across country genetic evaluation (MACE) is an advanced method used to run an international genetic evaluation (Schaeffer 1994). Essential requirements for a successful introduction of MACE in sport horse breeding are well established national genetic evaluations and a good genetic connectedness among countries (Árnason and Ricard 2001).

National genetic evaluations. The quality of the national genetic evaluations is crucial for an international comparison of EBVs. Until now, information on the quality of the statistical models in the different countries has been scarce. Statistical validation methods that have been developed in dairy cattle (Reverter *et al.* 1994; Boichard *et al.* 1995) may also be considered in horse breeding to validate and improve the quality of the genetic evaluation systems.

Genetic connectedness. Genetic connectedness across populations is a prerequisite for meaningful comparisons of EBVs across countries. The connectedness between two countries can be quantified as the average prediction error variance of differences in EBVs between both countries (Kennedy and Trus 1993). Estimates for the genetic connectedness among populations for sport horse breeding are not available, but are expected to be lower than in dairy cattle. One reason is that the progeny groups of sires are substantially smaller. A second reason may be the lower genetic correlations between traits in the different countries due to the large variation in data recording and genetic evaluation systems. But even when breeding objective traits are defined and recorded identically, genotype*environment interactions may reduce the possibilities of using EBVs from one country to predict EBVs in another country.

At present, the estimation of genetic connectedness among horse populations is complicated as horse identification numbers are not unique across organisations. Unique numbers are not only essential to connect pedigree information but also to link international performance data. In 2000, the WBFSH and the Fédération Equestre Internationale (FEI) proposed to introduce the Unique Equine Life Number (UELN) which is a 15 character number identifying the country and the studbooks of original registration of each horse (http://www.ueln.net). In the meantime breeding organisations may use preliminary cross-reference tables.

CONCLUSION

Present breeding programmes for sport horses vary largely with respect to breeding objectives and systems for testing and genetic evaluation. The low transparency of current breeding programmes constitutes a major obstacle for breeders when endeavouring to use genetic material from other countries optimally. Further validation and improvement of current methods will not only improve the selection efficiency of national breeding programmes but it will also establish the essential basis for an international genetic evaluation of sport horses.

ACKNOWLEDGMENTS

Financial support provided by KWPN, EAAP, WBFSH and ICAR is gratefully acknowledged.

REFERENCES

Aldridge, L.I., Kelleher, D.L., Reilly, M. and Brody, P.O.B. (2000) *J. Anim. Breed. Genet.* **117** : 65-72.
Árnason, T. (1987) *Livest. Prod. Sci.* **16** : 407-419.
Árnason, T. and Ricard, A. (2001) EAAP, Budapest, Hungary.
Árnason, T., Philipsson, G., Philipsson, J. (2001) « Rapport om BLUP avelsvärdering baserad på kvalitätsbedömningsresultat för fyraåriga ridhäster 1973–2000 ». IHBC AB, Knubbo, Morgongåva, Sweden.
Boichard, D., Bonati, B., Barabat, A. and Matilla, A. (1995) *J. Dairy Sci.* **78** : 431-437.
Bowden, V. (1982) *Anim. Breed. Abstr.* **50** : 147-162.
Brascamp, E.W. (1984) *Anim. Breed. Abstr.* **52** : 645-654.
Bruns, E. and Schade, W. (1998) *Proc. 6th WCGALP* **24** : 420-423.
Bruns, E., Schober, M. and Fredricson, I. (2001) EAAP, Budapest, Hungary.
Christmann, L. (1996) PhD Thesis, Georg-August-Universität, Göttingen, Germany.
De Vries, A.G. (1989) *Anim. Prod.* **48** : 221-227.
FN (2001) « Jahrbuch Zucht 2001/3 ». Fédération Equestre Nationale, Warendorf, Germany.
Hazel, L.N. (1943) *Genetics* **28** : 476-490.
Huizinga, H.A. and Van der Meij, G.J.W. (1989) *Livest. Prod. Sci.* **21** : 333-345.
Huizinga, H.A. (1991) PhD Thesis, Utrecht University, Utrecht, The Netherlands.
Janssens, S., Geysen, D. and Vandepitte, W. (1997) EAAP, Vienna, Austria.
Janssens, S. and Vandepitte, W. (2000) « Genetische spring index uitgebreid ». KU Leuven, Leuven, Belgium.
Jensen, P., Staun, H., and Fræhr, E. (1989) EAAP, Dublin, Ireland.
Kennedy, B.W. and Trus, D. (1993) *J. Anim. Sci.* **71** : 2341-2352.
Koenen, E.P.C. and Aldridge, L.I. (2001) EAAP, Budapest, Hungary.
Koenen, E.P.C., Van Veldhuizen, A.E. and Brascamp, E.W. (1995) *Livest. Prod. Sci*. **43** : 85-94.
Koerhuis, A.N.M. and Van der Werf, J.H.J. (1994) *Livest. Prod. Sci.* **40** : 207-213.
Philipsson, J., Brendow, E., Dalin, G. and Wallin, L. (1998) *Proc. 6th WCGALP* **24** : 408-415.
Reilly, M., Foran, M.K., Kelleher, D.L., Flanagan, M.J., and Brophy, P.O. (1998) *J. Anim. Breed. Genet.* **115** : 17-25.
Reverter, A., Golden, B.L., Bourdon, R.M. and Brinks, J.S. (1994) *J. Anim. Sci.* **72** : 34-37.
Ricard, A. (1988) *Proc. 6th WCGALP* **24** : 388-395.
Ricard, A., Bruns, E. and Cunningham, E.P. (2000) In « The Genetics of the Horse », p. 411-438, Editors A.T. Bowling and A. Ruvinsky, CAB International, Oxon, UK.
Ricard, A. and Chanu, I. (2001) *Genet. Sel. Evol.* **33** : 175-190.
Ricard, A. and Fournet-Hanocq, F. (1997) *Genet. Sel. Evol.* **29** : 251-267.
Schaeffer, L.R. (1994) *J. Dairy Sci.* **77**: 2671-2678.
SLU (2001) « The horse industry in the European Union. Final report EU Equus 2001 ». SLU, Uppsala, Sweden.
Tavenier, A. (1991) *Genet. Sel. Evol.* **23** : 159-173.
Von Velsen-Zerweck, A. (1998) PhD Thesis, Georg-August-Universität, Göttingen, Germany.
Wallin, L. (2001) PhD Thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.
Wallin, L., Strandberg, E. and Philipsson, J. (2001) *Livest. Prod. Sci.* **68** : 97-105.