Sveriges lantbruksuniversitet
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Genetic Analysis of Conformation and Performance Traits in the Swedish New Forest Pony Population

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Abstract

Since its foundation in 1967, the Swedish New Forest Pony Society (SNF) shows interest in breeding for performance in dressage, show jumping, and eventing competitions. The purpose of this study was to carry out genetic analyses on available recordings from young pony performance tests and competitions, in order to evaluate their usefulness in future selection for New Forest breeding ponies. Heritabilities, genetic correlations and breeding values were estimated using Best Linear Unbiased Prediction (BLUP) animal models. Data were composed of 467 ponies who participated in Young Pony Test (YPT) for 3-year olds between 2002-2014, 609 ponies who participated in Riding Pony Quality Test (RPQT) for 4- and 5-year olds between 1990-2014, lifetime competition results of 2225 ponies (that participated in dressage, show jumping and/or eventing between 1993-2011), and pedigree records for 60595 ponies.

Ten traits considering conformation, gaits and jumping ability were analysed in YPT and RPQT data, and four lifetime competition traits transformed with 10-log for each discipline (show jumping, dressage and eventing). Estimated heritabilities ranged from 0.06 (walk in hand) to 0.36 (jumping talent) in YPT, from 0.11 (jumping technique) to 0.62 (overall conformation) in RPQT, and from 0.00 (eventing) to 0.24 (show jumping) in competitions. Eventing data was not used for further analyses due to few participating ponies. Lifetime points in dressage and show jumping were found to be the most relevant traits to use for competition.

Within YPT, the highest positive genetic correlation was estimated between jumping technique and temperament for jumping (1.00). Conformation traits were similarly correlated with gaits (0.31 to 1.00) or with jumping traits (0.27 to 1.00), with one exception between trot in hand and correctness of legs (-0.12). The most strongly correlated gait with jumping traits was free canter (0.72 to 0.87). Within RPQT, all genetic correlations were positive, the highest being between overall conformation and temperament for gaits (0.84). Overall conformation had moderate to high but not significant correlations with jumping traits (0.29 to 0.49), and high correlations with gaits (0.53 to 0.70). The most strongly correlated gait with jumping traits was trot under rider (0.40 and 0.49) but not significantly. All significant genetic correlations between corresponding traits in YPT and RPQT were high (0.47 to 0.96). A few significant correlations were estimated between young pony test traits and competition traits, the highest being between jumping talent in RPQT and lifetime points in show jumping competitions (0.98).

The mostly moderate heritabilities and positive genetic correlations between young pony test traits and competition traits found in this study suggests that the traits are suitable to be used for future genetic evaluation of the breed. New Forest pony stallions having more than 10 tested or competed offspring were ranked according to their Estimated Breeding Values (EBVs) for talent traits in YPT and RPQT and two competition traits (lifetime points and ratio lifetime points/number of starts). However, the Swedish New Forest pony population is quite small and few ponies participate in YPT and RPQT, which contributes to less reliable genetic parameter estimations compared with larger populations. SNF should encourage breeders and owners to test their ponies in order to enable a reliable genetic evaluation for the breed in the future. All important traits should be stated in the breeding objectives and be measurable, which is not entirely the case for New Forest ponies.

Abbreviations

BLUP: best linear unbiased prediction
EBV: estimated breeding value
GW: Golden Wonder
HNS: Swedish Horse Council Foundation
NF: New Forest
NFPBCS: New Forest Pony Breeding and Cattle Society
NPFA: New Forest Pony Association
RHQT: riding horse quality test
RPQT: riding pony quality test
SH: Swedish Horse Board
SNF: Swedish New Forest society
SPAF: Swedish Pony Breeding Federation
SRF: Swedish Equestrian Federation
SWB: Swedish Warmblood Association (previously named ASVH)
YHT: young horse test
YPT: young pony test

1. Introduction

In Sweden, the New Forest is a popular versatile pony breed that mainly competes in dressage, show jumping and eventing, but also sometimes in driving and endurance. The Swedish New Forest society was founded in 1967 (SNF, 2015a) and shows interest in breeding for performance. Very few genetic studies of conformation and performance have been made on this breed in the country, however, Aminder (2002) carried out a genetic analysis for New Forest conformation traits using data from conformation shows for 2- and 3- year olds (premiering) and exhibition shows (utställning), but she did not focus on performance traits.

For horses, genetic analyses for several Warmblood breeds in Europe have shown that traits judged at young horse performance tests and competition traits have moderate to high heritabilities. Also, the traits assessed in the young horses show high positive genetic correlations with later competition results (Bruns et al., 2004; Thorén Hellsten, 2008). For these reasons, these traits are used nowadays by major European Warmblood breeding associations as a tool for selection as well as for genetic evaluations. In Sweden, results from Young Horse Test (YHT) for 3-year olds, Riding Horse Quality Test (RHQT) for 4- and 5-year olds, and from competitions, are used as a base for genetic evaluation of Swedish Warmblood stallions (Viklund, 2010).

The Connemara pony is the only pony breed for which genetic analysis of conformation and performance trait was carried out in Sweden, until now (Noréus, 2014). Genetic parameters were estimated using results from Young Pony Test (YPT) for 3-year olds, Riding Pony Quality Test (RPQT) for 4- and 5-year olds and competitions. The results showed that some test traits had statistically significant heritabilities and were positively correlated to competition traits, suggesting that this information could be used for future genetic evaluation, as it is actually the case for horse breeds.

The purpose of this study was to analyse conformation and performance traits for the Swedish New Forest pony population in the three main disciplines: dressage, jumping and eventing. Heritabilities were estimated for, and genetic correlations between, different conformation and performance traits from YPT, RPQT, and competition results. Given the usefulness of this information, it could be possible to estimate breeding values for stallions, using progeny results, own results and pedigree, in order to improve future selection in New Forest pony breeding.

2. Literature review

2.1 New Forest pony

2.1.1 History of the breed

New Forest ponies originated from the Hampshire County, on the South Coast of England in a forested area called “New Forest” (NPFA, 2013). The first ponies were crossed with Arab, Barb and Thoroughbred stallions throughout the years in order to improve their looks and increase their height. Crosses with these horses made the ponies graceful but not strong enough for the hard work in the forest. For this reason, the Society for the improvement of New Forest Ponies was established in 1891 to encourage farmers in improving the quality of their ponies by crossing with Highland, Dartmoor, Exmoor, Dales, Fell, and Welsh ponies (NFPBCS, 2011a). In 1905, the Burley and District New Forest Pony and Cattle Society was founded and started registering mares and young stock to then publish the first New Forest pony studbook in 1910 (NFPBCS, 2011b). Crossing with other breeds has been avoided since 1930 in order to maintain original characteristics of the breed. The two New Forest societies merged in 1938 to form the actual New Forest Pony Breeding and Cattle Society (NFPBCS) that established its own studbook in 1960. Five stallions are considered to be the founder of the modern New Forest breed: Brookside David (1943), Denny Danny (1943), Goodenough (1946), Broomy Slip-On (1948) and Knightwood Spitfire (1950) (SNF, 2015a).

Nowadays stud ponies, and semi-feral forest ponies that still live in the wild moorlands and marshes where they acquired robustness and rusticity qualities, can be distinguished (NPFA, 2013). Stud ponies are considered as elegant, high-quality riding ponies, with “horse-like” gaits and looks. These latter are now largely widespread in the world since they have been exported all over Europe, and even in North America and Australia. Many countries now have their own studbooks and breeding societies. The first New Forest ponies were imported in Sweden in the 50s and the Swedish New Forest Pony Society (SNF) was founded in 1967 (SNF, 2015a). SNF organises exhibitions, New Forest Championship and other activities such as competitions, shows and meetings to promote the breed in the country.

2.1.2 Standards

In general, New Forest ponies have an excellent temperament and their model allows both small children and adults to ride (NFPBCS, 2011c). They are robust riding ponies, but also very elegant. Types with a well-shaped head and a wide and flat forehead are appreciated. The neck should be well bonded, rather long and not too thick. Shoulders should present a nice slope, hindquarters should be powerful and the body of good depth with plenty of flat bones. They should also have straight limbs, round strong hooves and their gaits should be free and active without being excessive.

The size of New Forest ponies should not exceed 148cm and is rarely less than 120cm at withers (NFPBCS, 2011c). All coat colours are accepted except piebald, skewbald, spotted or cream colours with blue eyes. In order to be approved in the New Forest studbook, limited white markings are allowed on the head and legs (not above the knees/hocks). Stallions that are palomino, very light chestnut or cream colored with dark eyes cannot be approved.

2.1.3 Studbook division

In 1968, a New Forest stallion named Furzey Lodge Golden Wonder was mistaken with another stallion having the same name but which was not a New Forest pony (SNF, 2015b). By the time this confusion was discovered, the “imitation” Golden Wonder (GW) had been widely used in breeding and many of his colts were put into breeding as well. Three GW offspring have been exported and used for breeding in Sweden. Given that foreign blood is not accepted in the New Forest studbook since 1930, this resulted in a division of the Swedish New Forest studbook in two, one for ponies respecting the mother country rules and one for the others. However, between 1992 and 2012, the NFPBCS decided to allow offspring with a maximum of 6.25% GW blood to be registered in the official New Forest studbook.

Nowadays the following rules apply for the Swedish New Forest studbooks (SNF, 2015b):

- **Studbook section E**: this is the studbook following NFPBCS rules. Ponies registered must have a maximum of 6.25% GW blood and other requirements defined by the NFPBCS breed standard should be met. This studbook is entirely closed since 2012, meaning that in order to be registered; ponies should have both parents registered in this studbook as well, provided that they meet all the requirements of the breed defined by NFPBCS. The breed code corresponding to this studbook is 34.

- **Studbook section X**: this appendix studbook includes all New Forest ponies that do not meet the requirements and breed standards defined by the NFPBCS. Ponies having over 6.25% GW blood, presenting non-conforming white markings are included, as well as all ponies with deficiencies in the pedigree (e.g. parent not registered in studbook-E, ancestors with non-conforming white markings, non-Swedish pedigree, non-licensed stallions in the lineage). The breed code corresponding to this studbook is 39.

2.1.4 Swedish breeding objectives and statistics

The New Forest breeding objectives is to produce a pony that corresponds to the breed standards (NFPBCS, 2011c), that is a nice pony for the family, suitable for children and youths in all equine sport disciplines but that can also be ridden by adults, and that can be driven in competitions and easy work. Traditional selection criteria which emphasize soundness, durability, constitution, movements and type shall be kept (SNF, 2010). Today, breeding stallions are selected according to their results in performance tests, their own performance, or a combination of the two.

In 2014, there were 4100 New Forest ponies born between 1993 and 2012 that were registered and not reported as dead in Sweden, and there were 47 active New Forest pony breeders with at least one foal in two of the three years 2010 – 2012 (Lundqvist, 2014). The statistics for the breeds’ number of covered mares, registered foals and active stallions between 2009 and 2013 are shown in Table 1. As with other horse breeds in Sweden, there has been a significant decrease in the number of covered mares that could be due to the general economic crisis during the last years. It could be possible that mares from other breeds covered by New Forest stallions are included in the number of covered mares, explaining the rather low number of registered foals, which can only be purebred New Forest.

Table 1. *Number of covered mares, registered foals and active New Forest stallions in Sweden between 2009 and 2013*

	2009	2010	2011	2012	2013
Covered mares	242	203	172	94	94
Registered foals	124	112	106	104	48
Active stallions	46	41	30	27	26

2.2 Field tests for young ponies in Sweden

Ponies below 148cm at withers that are registered in Swedish breeding organizations associated with the Swedish Pony Breeding Federation (SPAF) can be evaluated by attending two different field tests: the Young Pony Test (YPT) for 3-year olds and the Riding Pony Quality Test (RPQT) for 4- and 5-year olds (Ungponny, 2015a and 2015b). These one-day tests are to a large extent conducted in the same way as the Young Horse Test (YHT) and Riding Horse Quality Test (RHQT) for Swedish Warmblood horses (Viklund, 2010).

YPT and RPQT are organized in order to improve pony breeds from the national studbooks being part of the SPAF (Ungponny, 2015a and 2015b). The aim is not to compare ponies with each other, but it is a chance to get a description of each individual pony's merits, weaknesses and future training opportunities. Results from YPT and RPQT can advise on ponies' possible best aptitudes in one discipline or another.

Today, phenotypic indices for conformation and quality of New Forest ponies are calculated by the Swedish Horse Board (SH) (SNF, 2011). These indices are based on results obtained in conformation shows for 2- and 3- year olds (premiering) and exhibition shows (utställning) organised by SNF, as well as results from YPT and RPQT reported to the SH. Stallions having at least 15 tested offspring are ranked for different traits evaluated in tests for young ponies.

2.2.1 Young Pony Test (YPT) for 3-year olds

YPT have been organised annually since 2002, at three locations each year (Ungponny, 2015a). The purpose of this test is to reflect talents and abilities of 3-year old ponies in different disciplines by giving scores corresponding to conformation, gait and jumping traits.

Ponies are evaluated at two different stations as described in Table 2. Conformation scores are given by an approved judge of the SH, and jumping scores are given by an approved judge and one or two aspirants. Scores for each trait evaluated in station 2 are given on a 10 point scale.

Scores obtained in each station are combined into total scores as follow (Ungponny, 2015a):

- A jumping talent score is calculated as the sum of scores for type, head-neck-body, correctness of legs, free canter, jumping technique and temperament for jumping.
- A gait talent score is calculated as the sum of scores for type, head-neck-body, correctness of legs, walk, trot and canter.

In each case the maximum score is 60, and a jumping or a gait talent award is given to ponies obtaining at least 47 points in total, with no sub-scores below 7 and a minimum score of 8 respectively in both jumping traits (technique and temperament) or in at least two of the three gait traits (walk, trot and canter).

Table 2. *Details of assessments and traits scored in each Young Pony Test (YPT) stations*

	Assessments	**Traits scored**
Station 1	ID inspection	
	Measurement at withers (for ponies without previous measurement certificate)	
Station 2	Conformation evaluation	Type Head-neck-body Correctness of legs and movements
	Gait evaluation	Locomotion of walk (in hand) Locomotion of trot (in hand) Locomotion of canter (free)
	Free jumping evaluation	Jumping technique Temperament for jumping

2.2.2 Riding Pony Quality Test (RPQT) for 4- and 5-year olds

RPQT has been carried out since 1978 and its purpose is to describe 4-and 5-year old ponies' abilities in different disciplines by giving scores corresponding to conformation, gait and jumping traits (Ungponny, 2015b).

During the test, ponies are given scores on conformation by approved pony judges of the SH, and on free jumping and gait traits by approved judges of the Swedish Warmblood Association (SWB). Each separate trait is given a score on a 10 point scale, and the evaluation is divided into four stations as described in Table 3.

For gait evaluation, the rating system takes in consideration several characteristics such as length of stride, energy, elasticity in movement, hind limbs activity (Ungponny, 2015b). In each jumping and gait evaluations, ponies' mental traits are also graded with scores given for temperament, manageability and general impression.

Scores obtained in each station are combined into total scores as follow (Ungponny, 2015b):

- Final score for jumping: C + (2 x J) + TJ / 4
- Final score for gaits: C + (2 x G) + (2 x R) / 5
- All-round final score: C + J + T + G / 4

Where:

C = mean overall conformation score (sum of type, head-neck-body, correctness of legs and of walk and trot in hand, divided by 5)
G = mean score for walk, trot and canter under rider
R = temperament for gaits score (rideability)
J = jumping technique score
TJ = score for temperament for jumping
T = overall score for temperament (mean score for rideability and temperament for jumping)

A jumping talent award is given for ponies obtaining at least 8 in the final score for jumping, with no sub-scores below 7 and a minimum score of 8 in both jumping traits (technique and temperament). A gait talent award is given for ponies obtaining at least 7.5 in the final score for gaits, with no sub-scores below 7 and a minimum score of 8 in at least one gait score (walk, trot or canter).

Table 3. *Details of assessments and traits scored in each Riding Pony Quality Test (RPQT) stations*

	Assessments	**Traits scored**
Station 1	ID inspection Measurement at withers (for ponies without previous measurement certificate)	
Station 2	Conformation evaluation	Type Head-neck-body Correctness of legs Locomotion in walk (in hand) Locomotion in trot (in hand)
Station 3	Free jumping evaluation	Jumping technique Temperament for jumping
Station 4	Gait evaluation (under rider)	Walk Trot Canter Temperament for gaits (rideability)

2.3 <u>Pony competitions in Sweden</u>

In Sweden, New Forest ponies mainly compete in show jumping, dressage and eventing. There are different difficulty classes for competitions in these three disciplines and there has been an update since 2010 with new appellations for the different difficulty classes (SRF, 2015a, b, c and d). For show jumping or eventing, height at withers defines the competition classes in which ponies can participate (SRF, 2015a and d). Four height categories are defined for ponies: (A) smaller than 107.0cm, (B) from 107.1 to 130.0cm, (C) from 130.1 to 140.0cm, and (D) from 140.1 to 148.0cm.

Ponies with placings, which correspond to the 25% best in a competition, receive a certain number of points. The point system is made so that more points are given for an equivalent placing in a higher class. In this manner, placed ponies receive a number of points that reflects both the placings and the level of competition.

2.3.1 Dressage

Before 2010, dressage classes were separated in two difficulty classes: easy (DL) and intermediate (DM) (SRF, 2015b and c). Each class was separated in sub-classes named A, B and C, with A being the most advanced class. Since 2010, there are new categories of dressage competitions for ponies. There are several different sub-classes divided in beginner, easy and intermediate classes.

2.3.2 Show jumping

Before 2010, show jumping classes were separated in three difficulty classes: easy (HL), intermediate (HM), and advanced (HS) (SRF, 2015a). The easy and intermediate classes were separated in sub-classes described in Table 4. Since 2010 show jumping competitions are named according to the size of the obstacles, and not using class names anymore.

Table 4. *Jump sizes (in cm) corresponding to different competition class names based on ponies' height at withers*

		Pony size			
Competition classes		**D** (140.1-148.0cm at withers)	**C** (130.1-140.0cm at withers)	**B** (107.1-130.0cm at withers)	**A** (< 107.0cm at withers)
Easy	HLD	80	70	60	50
	HLD+	85	75	65	55
	HLC	90	80	70	60
	HLC+	95	85	75	65
	HLB	100	90	80	70
	HLB+	105	95	85	75
	HLA	110	100	90	80
	HLA+	115	105	95	85
Intermediate	HMB	120	110	100	\
	HMB+	125	115	105	\
	HMA	130	120	110	\
Advanced	HS	135	\	\	\

2.3.3 Eventing

Before 2010, eventing classes were separated in three difficulty classes: beginner (FD), easy (FL) and intermediate (FM and FMA) (SRF, 2015d). Since 2010, there are new categories of eventing competitions for ponies. They are named P60, P70, P80 and P90, where the letter P indicates a pony class and the number indicates the maximum height of the cross-country fixed obstacles in centimetres. National classes are named CCNP and CNCP.

2.4 <u>Assessments for horses and ponies in Europe</u>

2.4.1 Performance testing schemes

In Europe, breed organisations use mainly records from three types of performance tests to evaluate young horses and ponies: stations tests, field tests, and competitions (Thorén Hellsten et al., 2006). In these tests, performance traits (jumping ability, gaits, rideability, etc.) and sometimes conformation traits (type, correctness of legs, general impression, etc.) are evaluated. Recorded conformation traits vary widely between test systems and countries and are scored either on a linear scale (Koenen et al., 1995) or a more subjective scale.

In station tests, both genders (each having specific separate tests) can be evaluated under uniform conditions, which minimize the effect of rider and training (Huizinga et al., 1991). Horses are mostly aged 3 to 4 years old and the time period of the test varies between countries and genders (from 8 days in Sweden, Great Britain and Hungary up to 100 days for stallions in Germany or The Netherlands) (Thorén Hellsten et al., 2006). Results from station tests have shown to have high heritabilities (0.40 to 0.60) and high genetic correlation to competition data

(0.70 to 0.90), showing their high relevance (Ricard et al., 2000). Nevertheless, this test is mainly used to evaluate stallions for breeding and very few horses and ponies participate due to the high costs, and horses are preselected due to criteria such as conformation, jumping or gaits (Thorén Hellsten et al., 2006).

Field tests (such as YHT, RHQT, YPT and RPQT in Sweden) are one-day tests (Thorén Hellsten et al., 2006). There are a larger number of horses and ponies participating compared to station tests but results have shown to be less heritable (0.10 to 0.30) and have a slightly lower genetic correlation with competition data (0.65) (Ricard et al., 2000). This latter can be explained due to the shorter time period of the tests and pre-training of horses and ponies can introduce bias (Koenen and Aldridge, 2002). These tests are however essential to increase efficiency of selection of sport horses of each gender.

Horse and pony competitions open to both genders (dressage, show jumping and eventing) are also used as a base for genetic evaluation (Belgium, France and Ireland) or as an additional test to performance tests (Thorén Hellsten, 2008). Main traits recorded depend on the countries (scores, earnings or placings, wins, etc.) (Koenen and Aldridge, 2002). There is a relatively low repeatability but it enables to record large amounts of data for lower costs than station or field tests. Similarly to field tests, estimated heritabilities for competition traits range from 0.10 to 0.30 (Ricard et al., 2000), but it is important to note that in this latter there is a quite high preselection and recordings are made later in life.

Even though they have different procedures, recordings in all these tests have enabled genetic studies on conformation and performance traits of young horses and ponies in several European countries (Thorén Hellsten, 2008). Recorded information enables to estimate genetic parameters for each trait of the breeding goal: in order to achieve genetic progress for sport horses and ponies, heritabilities of the traits should be moderate and should show strong positive genetic correlations with later competition results.

2.4.2 Genetic evaluation

Genetic evaluation for performance traits is either based only on competition results (Belgium, France and Ireland) or on combined competition and performance test results (Germany, The Netherlands and more recently Denmark and Sweden) (Koenen and Aldridge, 2002; Bølling, 2011; Viklund et al., 2011). In Sweden, RHQT data alone was used for estimating breeding values for the Swedish Warmblood horse since 1986 (Árnason, 1987). YHT and competition data were then included in 2006 to provide a more accurate evaluation (Viklund, 2010). For competition results, performance data (ranks, scores, earnings, etc.) is often transformed in order to achieve a more normal distribution of the data.

The BLUP (Best Linear Unbiased Prediction) animal model is used for genetic evaluation of many breeds in European countries such as Sweden, France, Belgium, Denmark, Germany, Ireland and The Netherlands (Árnason and Van Vleck, 2000). Within the statistical models, fixed factors such as sex, age, birth year, rider, year and location of test are adjusted for (Viklund, 2010).

2.4.3 Estimated genetic parameters

2.4.3.1 Tests for young ponies and horses

Genetic analyses of conformation and performance traits have been made in several horse breeds, but there is a lack of similar studies in pony breeds. Moreover, since the systems used to score conformation traits are very different between studies and countries, results are not always comparable.

A. Heritabilities

a. Conformation traits

Aminder (2002) estimated heritabilities for New Forest and Connemara ponies at conformation shows for 2- and 3- year olds (premiering) and exhibition shows (utställning) in Sweden. In both shows, low to moderate heritabilities for conformation traits were estimated for both New Forest (0.15 to 0.33) and Connemara ponies (0.05 to 0.25). Heritability estimate for overall conformation score was higher for New Forest (0.56) than for Connemara (0.26). Noréus (2014) estimated heritabilities for each conformation trait evaluated in YPT in the range 0.04 to 0.50 for Connemara ponies, with the lowest being for correctness of legs. Heritability estimate for overall conformation score in RPQT was low (0.18). For German Riding Pony foals, Schöpke and Swalve (2012) estimated low heritability for overall conformation score (0.16), but high for type (0.61). Estimated heritabilities for mares were high (0.50 to 0.70), except for legs (0.18-0.26). Samoré et al. (1997) studied several conformation traits in Haflinger ponies using a multi-trait animal model, and estimated low to high heritabilities (0.02 to 0.53), with low to moderate heritabilities for traits such as neck-body connection (0.15) and head-neck connection (0.24).

Two studies by Viklund et al. (2008) and Jönsson et al. (2014b) on Swedish Warmblood horses showed similar pattern with moderate to high heritabilities for all conformation traits evaluated at young horse tests (0.24 to 0.58 and 0.20 to 0.36, respectively), except for correctness of legs (0.08 and 0.06, respectively). Viklund et al. (2008) also estimated high heritabilities for overall conformation score at both YHT and RHQT (0.58 and 0.55, respectively). In another study by Wallin et al., (2003) on Swedish Warmbloods that participated in RHQT, slightly lower heritability was estimated for overall conformation (0.33).

For conformation, linear scoring of specific traits, on a continuous scale between two extremes, has been used in some breeds as a base for genetic evaluation. This linear description has the advantage of being more objective than regular scoring. Van Bergen & Arendonk (1993) estimated low to moderate heritabilities for 28 linear conformation traits in the Shetland pony population in the Netherlands (0.07 to 0.39). For horse breeds, Koenen et al. (1995) estimated similar heritabilities for 26 linear conformation traits in Dutch Warmblood mares (0.09 to 0.28) and Rustin et al. (2009) estimated low to high heritabilities for 27 linear conformation traits in Belgian Warmbloods (0.15 to 0.55). In those three studies, traits for legs were reported as part of the ones having the lowest heritabilities of all conformation traits, similarly to what was reported in other studies on both horses and ponies (Aminder, 2002; Viklund et al., 2008; Jönsson et al., 2014b; Noréus, 2014).

b. Gait traits

For gait traits in ponies, Noréus (2014) estimated low to moderate heritabilities for Connemara ponies for gaits in YPT (0.04 to 0.38) and RPQT (0.03 to 0.37). Aminder (2002) estimated moderate to high heritabilities for walk and trot in conformation shows and exhibition shows for both New Forest (0.22-0.33 and 0.40-0.44, respectively) and Connemara ponies (0.24-0.13 and 0.33, respectively). Similar heritabilities were estimated for Shetland ponies by Van Bergen & Arendonk (1993) for walk and trot traits stride and suppleness (0.27 to 0.41). For gaits of the German Riding Pony, Schöpke and Swalve (2012) estimated moderate heritabilities for foals (0.31) or high for mares (0.39-0.48), except for correctness of gaits (0.12). This is similar to what was reported for gait traits in horses. Viklund et al. (2008) estimated moderate to high heritabilities for all gaits in both YHT and RHQT for Swedish Warmbloods (0.31 to 0.53). Becker et al. (2011) and Luehrs-Benke et al (2002) analysed performance tests results from German Warmblood mares and German Warmblood stallions respectively, and estimated moderate heritabilities for gaits (0.33 to 0.51). There were also slightly higher heritabilities for gaits showed in hand rather than under rider (Becker et al., 2011). Rustin et al. (2009) estimated moderate heritabilities for 6 linear gait traits in Belgian Warmbloods (0.33 to 0.47). For Dutch Warmbloods, heritability estimates for gaits were reported slightly lower by Ducro et al. (2007) (0.15 to 0.32) and Koenen et al. (1995) (0.12 to 0.22).

c. Jumping traits

For Connemara ponies, Noréus (2014) estimated moderate heritabilities for jumping traits in both YPT (0.26 to 0.33) and RPQT (0.25 to 0.33). For horses, similar heritabilities were estimated by Viklund et al., (2008) for jumping traits in Swedish Warmbloods (0.17 and 0.33), by Ducro et al. (2007) for Dutch Warmbloods (0.22 to 0.37), and by Luehrs-Behnke et al. (2002) for German Warmbloods (0.33 to 0.39).

B. Genetic correlations

a. Between tests types

Genetic correlations between similar traits in the different tests were estimated in various studies of young horses or ponies. For Connemara ponies, Noréus (2014) estimated high positive genetic correlations between corresponding traits for gaits in YPT and RPQT (0.78 to 0.90). Similarly, Aminder (2002) reported that all corresponding traits recorded between conformation shows and exhibition shows for young ponies were highly correlated for Connemara ponies (0.59 to 1.0). The same tendency was found for New Forest ponies (0.63 to 0.93), except for head-neck-body (-0.26).

For horses, Viklund et al. (2008) also estimated high positive genetic correlations between each corresponding trait in YHT and RHQT for performance and conformation in Swedish Warmbloods (0.82 to 0.99).

b. Between conformation traits

For Connemara ponies, Noréus (2014) found high positive genetic correlations between head-neck body and correctness of legs (0.83) within YPT. Other analyses did not reach convergence because the population studied was too small. Aminder (2002) found moderate to high positive genetic correlations within conformation and exhibition shows between the different conformation traits for New Forest (0.31 to 1.0 and 0.72 to 0.92, respectively) and Connemara ponies (0.63 to 0.95 and 0.72 to 0.76, respectively). The highest correlations were between type and head-neck-body for New Forest ponies and between type and correctness of legs for Connemara ponies. In both shows, estimated genetic correlations were high between overall conformation score and other conformation traits for New Forest (0.73 to 0.92 and 0.57 to 0.83, respectively) and Connemara ponies (0.57 to 1.0 and 0.84 to 0.86, respectively). For German Riding Pony foals, Schöpke and Swalve (2012) estimated high positive genetic correlation between overall conformation and type (0.78).

For horse breeds, Viklund et al. (2008) found moderate to high positive genetic correlations between conformation traits within both YHT and RHQT. The highest correlation was between type and head-neck-body (0.43 in YHT and 0.42 in RHQT). The only exception was for correctness of legs that showed low genetic correlations with other conformation traits (0.05 to 0.12 in YHT and 0.02 to 0.07 in RHQT). This tendency was also reported by Jönsson et al. (2014b) that estimated positive genetic correlations among all conformation traits (0.20 to 0.89) except for legs (-0.19 to 0.06) for Swedish Warmbloods.

c. Between gait traits

For ponies, Noréus (2014) estimated high positive genetic correlations between different gaits within YPT (0.63-0.87), except between walk and canter under rider (-0.01). Temperament for gaits showed high correlations with walk under rider and trot under rider (0.38 and 1.0, respectively). When using data from conformation and exhibition shows for young ponies in Sweden, Aminder (2002) found moderate genetic correlations between walk and trot for New Forest (0.67 and 0.96, respectively) and Connemara ponies (0.66 and 0.74, respectively). High genetic correlations were estimated for Shetland ponies by Van Bergen & Arendonk (1993) between walk and trot traits stride and suppleness (0.84 to 0.94).

For horse breeds Viklund et al. (2008) estimated strong positive genetic correlations between gait traits within tests (0.43 to 0.68 in YHT and 0.58 to 0.75 in RHQT). Similar results were reported for German Warmbloods by Becker et al. (2011) between all gaits free or under rider as well as between average of all gaits free or under rider (0.92).

d. Between jumping traits

The two jumping traits within tests for young horses and ponies (jumping technique and temperament for jumping) showed strong positive genetic correlations both for Connemara ponies (0.98) according to Noréus (2014), and for Swedish Warmblood horses (0.97 in both YHT and RHQT) according to Viklund et al. (2008).

e. Between gait and jumping traits

For Connemara ponies, Noréus (2014) found that the gait being most strongly correlated with jumping traits was trot in hand in YPT (0.19-0.25) and canter under rider in RPQT (0.69-0.87). In YPT, walk and canter were both negatively correlated to jumping traits (-0.40 to -0.18). In RPQT, walk and trot both showed moderate to high positive genetic correlations with jumping traits (0.30 to 0.49). These results are different from what was reported in horse breeds, were canter was the only gait showing significant positive genetic correlations with jumping traits (Ducro et al., 2007; Viklund et al., 2008).

f. Between gait and conformation traits

For New Forest ponies, Aminder (2002) found moderate to high genetic correlations between gait traits (walk and trot) and the different conformation traits in both conformation and exhibition shows (0.21 to 0.87 and 0.43 to 0.59, respectively). For Connemara ponies, the same tendency was reported (0.36 to 1.0 and 0.46 to 0.70, respectively), except between head-neck-body and gaits in conformation shows (-0.18 and -0.07). In both types of shows, genetic correlations were high between overall conformation score and gaits for both New Forest (0.70-0.96 and 0.84-0.86, respectively) and Connemara ponies (0.75-0.80 and 0.80-0.86, respectively). Noréus (2014) found low to high positive genetic correlations between gaits and conformation traits within YPT (0.13 to 0.93) for Connemara ponies, except between head-neck-body and free canter (-0.70) but not significantly. Within RPQT, genetic correlations were moderate between overall conformation score and gait traits (0.19 to 0.55). Similar genetic correlation between overall conformation and gaits has been reported by Schöpke and Swalve (2012) in German Riding Pony foals (0.71).

Within YHT and RHQT for Swedish Warmblood horses, Viklund et al. (2008) estimated moderate to high positive genetic correlations between gaits and conformation traits (0.28 to 0.57 in YHT and 0.20 to 0.62 in RHQT), except for correctness of legs (0.05 to 0.12 in YHT and 0.02 to 0.06 in RHQT). Following a similar pattern, Ducro et al. (2007) estimated high genetic correlations between different gaits and conformation traits for Dutch Warmbloods (0.28 to 0.49) except for correctness of walk (-0.02).

g. Between jumping and conformation traits

For Connemara ponies, Noréus (2014) estimated negative genetic correlations between conformation and jumping traits in YPT (-0.34 to -0.01) and moderate genetic correlations between overall conformation and jumping traits in RPQT (0.28 to 0.49).

For Swedish Warmblood horses, Viklund et al. (2008) estimated low but positive correlations between conformation and jumping (0.07 to 0.23). Similar results were reported by Ducro et al. (2007) for Dutch Warmbloods (0.17).

Studies on both ponies and horses tend to show that the assessed conformation traits have a lower impact on jumping performance than on dressage performance.

2.4.3.2 Competitions

A. Heritabilities

For ponies, very few studies have been done on genetic analysis for competition traits compared with horses. Noréus (2014) estimated moderate heritabilities for total points in each of the disciplines dressage (0.31), show jumping (0.35) and eventing (0.22) for Connemara ponies. Ricard (2004) estimated heritabilities of jumping ability and they slightly differed when category of competition was corrected for or not for the French Riding pony (0.06 and 0.05, respectively), Connemara (0.13 and 0.10, respectively) and New Forest (0.16 and 0.19, respectively).

For horses, Huizinga and van der Meij (1989), Koenen et al. (1995), and Ducro et al. (2007) have estimated low heritabilities for dressage for Dutch Warmbloods (0.10, 0.17 and 0.14 respectively). Similar results for dressage were reported for Swedish Warmbloods by Viklund et al. (2010) (0.07 to 0.16), and by Wallin et al. (2003) for both cumulative points and cumulative placings in dressage (0.16 and 0.17 respectively). A study by Stewart et al. (2009) showed similar heritabilities for dressage in Great Britain (0.11-0.15).

For show jumping, estimated heritabilities varied somewhat more than for dressage. For Dutch Warmbloods, Huizinga and van der Meij (1989), Koenen et al. (1995) and Ducro et al. (2007) found low to moderate heritabilities (0.20, 0.19 and 0.14 respectively). For Swedish Warmbloods, Viklund et al. (2010) reported similar results for show jumping (0.12 to 0.28) and Wallin et al. (2003) estimated slightly higher heritabilities for both cumulative points and cumulative placings in jumping (0.23 and 0.27 respectively).

From what was shown in most studies, show jumping and dressage competition results often give lower heritabilities that gaits and jumping traits in young horse tests. This can be explained since in competition horses can be much more influenced by environmental factors such as rider or training (Viklund, 2010).

Compared to show jumping and dressage, only a few studies have done genetic evaluation of eventing traits due to the lower number of participations. In Sweden, Ray (2012) analysed points, placings, and points per placing in eventing for Swedish Warmblood horses. Estimated heritabilities for lifetime results of overall eventing were low (0.06 to 0.16). For eventing competitions in France, Ricard and Chanu (2001) estimated low heritabilities for annual earnings, annual earnings per start and per place (0.11 to 0.17). In the UK, Kearsley et al. (2008) analysed penalty points in eventing and estimated lower heritability for overall eventing (0.05) compared with individual disciplines show jumping (0.08 to 0.23) and dressage 80.09 to 0.11) within the eventing competition. These results suggested that combining all eventing disciplines in a single trait is less effective than examining each discipline separately in order to identify genetically superior horses.

B. Genetic correlations

a. *Between conformation traits and competition traits*

For Connemara ponies, Noréus (2014) estimated zero to low genetic correlations between overall conformation score in RPQT and dressage (0.0) or show jumping (-0.25). Moderate negative to low positive genetic correlations were reported in YPT between each conformation trait and dressage (-0.44 to 0.11). Similar genetic correlations were estimated between conformation traits and show jumping (-0.46 to -0.09), except for correctness of legs (0.63).

For horses, moderate to high positive genetic correlations were estimated between conformation traits in performance tests and dressage by Wallin et al. (2003) for Swedish Warmbloods (0.37 and 0.38) and by Ducro et al. (2007) for Dutch Warmbloods (0.67). Slightly lower genetic correlations were found for Swedish Warmbloods by Viklund et al. (2010) between conformation traits scored in RHQT and both dressage (0.15 to 0.71) and show jumping results (0.19 to 0.34), and by Jönsson et al. (2014a) (0.15 to 0.30). This is not what was reported for Dutch Warmbloods by Koenen et al. (1995), with moderate or high negative to low positive genetic correlations between conformation traits and both dressage (-0.49 to 0.15), and show jumping (-0.28 to 0.12). However, the more recent study on Dutch Warmbloods by Ducro et al. (2007) estimated a higher positive genetic correlation between conformation and dressage (0.29).

b. *Between gait and jumping traits, and competition traits*

For Connemara ponies, Noréus (2014) found moderate to high negative genetic correlations between dressage and gait traits in YPT (-0.41 to -0.36), but not significant; and high and positive correlations between dressage and gait traits in RPQT (0.39 to 0.54). Between each gait in young pony tests and show jumping, genetic correlations were negative and moderate to high in YPT (-0.83 to -0.22) and high negative to low positive in RPQT (-0.74 to 0.13). Canter was the most correlated gait with show jumping in RPQT, but the least correlated in YPT. Jumping traits scored in both YPT and RPQT (temperament for jumping and jumping technique) both had high positive genetic correlations with show jumping (0.36 to 0.69), but low to high negative with dressage (-0.43 to -0.04), except between temperament for jumping in YPT and dressage (0.34).

For Swedish Warmblood horses, Viklund et al. (2010) and Wallin et al. (2003) analysed RHQT traits (including temperament for gaits and temperament for jumping) and performance in competition. High positive genetic correlations were estimated between all gait traits in RHQT and dressage (0.47 to 0.77 and 0.63 to 0.75, respectively), and between jumping traits in RPQT and show jumping (0.88 to 0.89 and 0.88 to 0.93, respectively). Similar genetic correlations were estimated by Ducro et al. (2007) for Dutch Warmbloods evaluated in young horse tests: high genetic correlations between gait traits and dressage (0.40 to 0.67), except for correctness of walk (0.05), and between all jumping traits and show jumping results (0.52 to 0.88).

In contrast, weak or negative genetic correlations were estimated between jumping traits in young horse tests and dressage results by Viklund et al. (2010) (-0.19 to 0.02), Wallin et al. (2003) (0.06 to 0.10), and by Ducro et al. (2007) (-0.43 to -0.09). The same tendency was reported between gait traits in young horse tests and show jumping results with low to moderate genetic correlations by Viklund et al. (2010) (-0.01 to 0.18), Wallin et al. (2003) (-0.05 to 0.33), and by Ducro et al. (2007) (0.04 to 0.14), with an exception for canter in the three studies (0.33 to 0.39, 0.24 to 0.60, and 0.28 to 0.43, respectively).

Most of the time, trot was found to be the gait with greatest importance for a successful dressage career and canter was the most correlated to show jumping results (Viklund et al., 2010; Wallin et al., 2003; Ducro et al., 2007).

For eventing data, Ray (2012) found positive low to moderate genetic correlations between traits evaluated in RHQT and lifetime points in eventing for Swedish Warmbloods (0.14 to 0.41), except for trot in RHQT (-0.06). Ricard and Chanu (2001) found high genetic correlations between eventing and jumping (0.45) and between eventing and dressage (0.58). These results suggested that within the tested population, selection for show jumping and dressage will have a positive effect on eventing. Similar results were reported by Kearsley et al. (2008) that found that both show jumping and dressage were positively correlated to overall eventing competition. The highest correlation was estimated between dressage and overall eventing (0.8) and the lowest between show jumping and dressage (0.13). For lifetime points, Ray (2012) estimated moderate genetic correlations between eventing and jumping (0.44) but eventing and dressage were uncorrelated (-0.01).

3. Material & Methods

3.1 Material

The material included in the study was composed of data from YPT, RPQT, and competition of Swedish New Forest ponies and pedigree records, all in the form of Excel files. Data was obtained from the Swedish Horse Board (SH), via the Swedish New Forest Society (SNF).

3.1.1 Young Pony Test

Data included 470 observations of New Forest ponies participating in YPT between 2002 and 2014. The following information was available for the ponies: identity numbers, name, suffix (origin and studbook number for breeding ponies), breed code (34 or 39), location in which the test took place, date, judge, and scores for conformation, gait, and jumping traits. Information such as judge was only available for some ponies, but the same judges evaluated all ponies in a given event (unique combination of year and location). The conformation traits for which a score was given were type, head-neck-body and correctness of legs. The gait traits recorded were walk and trot in hand, and free canter, and the jumping traits were jumping technique and temperament for jumping.

As two ponies had participated twice in the same year, only the participation with highest total score was kept. Information for one pony was also excluded because of missing scores for several traits. After excluding these records, the data used in analysis represented 467 unique participations in which 56.1% were mares and 43.9% were stallions or geldings.

The YPT took place at 38 different locations in 13 different years, resulting in a total number of 106 different events. The mean number of participation per year was 35.9 with a minimum of 22 in 2002 and a maximum of 51 in 2008. The mean number of participation per event was 20.3 with a minimum of 1 and a maximum of 51. The number of registered New Forest foals in Sweden was between 106 and 124 in the years 2009-2011 (Lundqvist 2014) and 16 to 28 ponies participated in YPT three years later (2012-2013).

All ponies had known parents and were the progeny of 92 sires and 313 dams in total. Sires had 1 to 34 offspring participating in YPT, with a mean of 5.0 offspring per stallion. Dams had 1 to 7 offspring participating in YPT, with a mean of 1.5 offspring per mare. Details of analysed data are shown in Table 5.

3.1.2 Riding Pony Quality Test

Data included 626 observations of New Forest ponies participating in RPQT between 1990 and 2014. The following information was available for the ponies: identity numbers (id), name, suffix, breed code (34 or 39), place in which the test took place, date, judge, scores for two veterinary health check-up stations, scores for gait and jumping traits, and a total score for conformation. Information such as judge, or score for veterinary stations was only available for some ponies.

Gait traits recorded were walk, trot and canter under rider, as well as temperament for gaits (rideability). Jumping traits recorded were jumping technique and temperament for jumping. Two veterinary health check-up stations previously gave scores for health status and temperament, but one station was removed in 2006 and the other in 2011. Ponies evaluated after these years did not obtain these scores. For these reasons, analyses of scores obtained in these two stations were not carried out. The overall score for conformation was calculated by adding sub-scores for the traits type, head-neck-body, correctness of legs, walk and trot; giving a total score out of 50. The sub-scores were not available in the data so only overall conformation was used.

As 15 ponies had participated twice in different years, only the most complete result was used. If all evaluated traits had scores, the highest score compensated for the age difference was used. Information for two ponies was excluded because of missing scores for several traits. After editing, the data used in analysis represented 609 unique participations in which 47.8% were mares and 52.2% were stallions or geldings. The age distribution at test was 66.8% 4-year old ponies and 33.2% 5-year old ponies.

The RPQT took place in 36 different places in 25 different years, resulting in a total number of 111 different events. The mean number of participation per year was 24.4 with a minimum of 2 in 1990 and a maximum of 43 in 2000. The mean number of participation per event was 16.6 with a minimum of 1 and a maximum of 43. Out of the 106 to 124 New Forest foals registered in Sweden in the years 2009-2011 (Lundqvist 2014), 16 ponies participated in RPQT 4 years later (in 2013 and in 2014).

All ponies had known parents and were the progeny of 136 sires and 409 dams in total. Sires had 1 to 38 offspring participating in RPQT, with a mean of 4.5 offspring per stallion. Dams had 1 to 7 offspring participating in RPQT, with a mean of 1.5 offspring per mare. 138 ponies had participated in both YPT and RPQT. Details of analysed data are shown in Table 5.

3.1.3 Competition data

Competition data was collected between 1993 and 2011, and included results from 2420 ponies with a total of 7928 annual records. From the data 609 incomplete records were excluded: the records did not indicate either discipline, class, starts, winning and/or placing but only the total points obtained (599 records from the years 1992 and 1993, and 10 records from the years 1993-2010 were removed). Records from three ponies lacking licence number were excluded. All other records had this information, as well as pony identity numbers (id), name, suffix, breed code (34 or 39), and date of competition.

Only records for the three main disciplines dressage, show jumping, and eventing were kept: 95 annual records for other disciplines were removed because too few ponies participated (2 endurance, 10 gallop racing and 83 driving records). For more homogeneity in the analysis, all competition data after 2010 was formatted following the appellations for competition classes given before 2010. Lifetime results were then compiled so that each pony had only one row including all competitions from all years in which it competed.

After editing, the data contained a total of 7221 annual records being the results from 2225 unique ponies, including 1536 ponies that participated at least twice in competitions. This included 5188 annual jumping records (1714 unique ponies), 2116 annual dressage records (784 unique ponies) and 675 annual eventing records (322 unique ponies). One pony had unknown parents and sex, four ponies had unknown dam, and five ponies had unknown birth years.
The mean number of records per year was 380 with a minimum of 253 in 1994 and a maximum of 559 in 2007. Amongst the participating ponies, 41.8% were mares and 58.2% were stallions or geldings. For ponies with known birth years, they took part in competitions between the age of 4 and 29 years old, with the mean age being 11.2 years old.

All ponies having known parents were the progeny of 283 sires and 1450 dams in total. Sires had 1 to 59 offspring participating in competitions, with a mean of 7.8 offspring per stallion. Dams had 1 to 12 offspring participating in competition, with a mean of 1.5 offspring per mare. 104 ponies participated in both YPT and competitions, 285 in both RPQT and competitions and 49 ponies have participated in all three (YPT, RPQT and competitions). Details of analysed data are shown in Table 5.

Four competition traits per discipline were chosen for the analyses:

- **Lifetime points**: it is a good indicator of performance since it reflects both the placings and the level of competition, as well as sustainability in competition
- **Number of wins + number of placings** : it reflects how the ponies had wins and placings, but it does not reflect the level of competition
- **Ratio lifetime points/(wins + placings)**: reflects wins, placings and level of competition
- **Ratio lifetime points/number of starts**: reflects both placings and level of competition as well as how many times ponies started in competition

Table 5. *Summary of analysed data for ponies evaluated in Young Pony Test, Riding Pony Quality Test and competitions*

	YPT	RPQT	Competition
Time period	2002 - 2014	1990 - 2014	1993 - 2011
Average participations per year	*35.9*	*24.4*	*380*
Number of ponies with unique participations	**467**	**609 (407 4-year olds and 202 5-year olds)**	**2225**
Number of mares	262	291	929
Number of stallions/geldings	205	318	1295
Number of sires	92	136	283
Average offspring per sire	*5*	*4.5*	*7.8*
Number of dams	313	409	1450
Average offspring per dam	*1.5*	*1.5*	*1.5*
Number of events (unique date*place)	106	111	/
Average participations in events	*4.2*	*5.5*	*/*

3.1.4 Pedigree data

Pedigree data consisted of files containing information for 60595 ponies including 43248 mares and 17347 stallion and geldings. The data included pony identity numbers (id), name, eventual suffix, id of father, id of mother, sex, birth year, and breed code (34 or 39). Some ponies had unknown parents and only 20.9% had known birth dates. The average coefficient of pedigree completeness index (PEC) (MacCluer et al., 1983), based on five ancestor generations was 0.61 for the total pedigree file, 0.92 for the ponies with own performance (in tests for young horses and/or competitions) and 0.82 for stallions having at least 10 tested or competed offspring.

3.2 Methods

Statistical Analysis Systems (SAS) software, version 9.4 was used for data management and descriptive statistics (SAS, 2015). Fixed effects included in the final statistical models were chosen after analysis of variance using the GLM procedure in SAS:

- For YPT, sex and event were significant ($p<0.05$) for few traits, but the R^2 (coefficient of determination) showed that 23% to 31% of the variation could be ascribed to the model including both tested effects.
- For RPQT, sex, event and age were either highly significant ($p<0.001$) or significant ($p<0.05$) for most traits, and the R^2 showed that 24% to 34% of the variation could be ascribed to the model including all three tested effects.
- For competition, sex and birth year were either highly significant ($p<0.001$) or significant ($p<0.05$) for most traits, and the R^2 showed that 5% to 28% of the variation could be ascribed to the model including both tested effects.

For each discipline (dressage, show jumping and eventing), the competition traits tested in the model (lifetime points, wins + placings, ratio points/(wins + placings) and ratio points/number of starts) were transformed with 10-log to have a more normal distribution of data. A point was added beforehand to enable transforming with 10-log for horses with no points or wins and placings.

The following BLUP multivariate mixed animal models were used:

For YPT: $Y_{ijm} = \mu + sex_i + event_j + individual_m + e_{ijm}$

For RPQT: $Y_{ijkm} = \mu + sex_i + event_j + age_k + individual_m + e_{ijkm}$

For competition: $Y_{ilm} = \mu + sex_i + birth\ year_l + individual_m + e_{ilm}$

Where:

Y = observed value for the m^th pony

μ = population mean value for the traits

$\mathbf{sex_i}$ = fixed effect of sex, i = mare or stallion/gelding

$\mathbf{event_j}$ = fixed effect of event (location*year), j = event in YPT and RPQT

$\mathbf{age_k}$ = fixed effect of age, k = 4- or 5-years old (age of ponies participating in RPQT)

$\mathbf{birth\ year_l}$ = fixed effect of birth year, l = 1970 to 2006 (birth years of ponies participating in competitions)

$\mathbf{individual_m}$ = additive random genetic effect of the m^{th} pony ~ ND (0, $\mathbf{A}\sigma_a^2$)

e = random residual effect ~ ND (0, σ_e^2)

Genetic analyses (genetic parameter and breeding value estimations) were carried out using the average information algorithm (Jensen et al., 1997) in the DMU software package for analysing multivariate mixed models (Madsen and Jensen, 2013). Individual trait estimations were performed using univariate analyses and correlations between traits were estimated using bivariate analyses. Single trait breeding values were estimated in order to be used for ranking potential breeding animals for traits of interest: talent traits in YPT and RPQT and the competition traits lifetime points in each discipline, and ratio lifetime points/number of starts in dressage and show jumping.

Heritabilities (h^2) were calculated as $h^2 = \sigma^2_a / \sigma^2_p$

Where:

σ^2_a = additive genetic variance
σ^2_p = phenotypic variance

Genetic correlations (r_g) between two traits (x, y) calculated as $r_g = \sigma^2_{xy} / (\sigma^2_x * \sigma^2_y)^{½}$

Where:

σ^2_{xy} = additive genetic covariance between traits x and y
σ^2_x = additive genetic variance for trait x
σ^2_y = additive genetic variance for trait y

Phenotypic correlations (r_p) between two traits (x, y) calculated as $r_p = \sigma^2_{pxpy} / (\sigma^2_{px} * \sigma^2_{py})^{½}$

Where:

σ^2_{pxpy} = phenotypic covariance between traits x and y
σ^2_{px} = phenotypic variance for trait x
σ^2_{py} = phenotypic variance for trait y

Most analyses met a convergence criterion for the norm vector of $<10^{-7}$, except for some bivariate analysis, which usually means that it is difficult to discriminate as the tested traits are closely related. These analysis met the convergence criterion for the norm vector of $<10^{-5}$.

4. Results

4.1 <u>Young Pony Test</u>

4.1.1 Descriptive statistics

Eight traits in total were scored in YPT. For conformation and gait traits, mean scores ranged between 7.1 and 7.9 out of the 10 points scale, with the lowest being for canter and the highest for type. No scores under 5 were given for these traits. For the two jumping traits, mean scores were slightly lower (7.1 for temperament for jumping and 7.0 for jumping technique) and the given scores ranged from 1 to 10.

Out of 60, the highest scores were similar for gait talent (52) and jumping talent (53), and the lowest score was slightly higher for gait talent (38) than for jumping talent (30). When adding all scores for the eight tested traits in YPT, the range for overall score was 44-70 out of 80, and the mean was 59.3. Statistics for scores given in YPT are shown in Table 6.

Table 6. *Number of observations (N), mean score ($\bar{x}$), standard deviation (S.D.), minimum (Min) and maximum (Max) scores for traits evaluated in Young Pony Test (YPT) from 2002 to 2014*

YPT trait	N	Maximum score on scale	Min	Max	$\bar{x}$	S.D.
Type	467	10	6	9	7.9	0.6
Head-Neck-Body	467	10	6	9	7.6	0.6
Correctness of legs	467	10	5	9	7.4	0.6
Walk in hand	467	10	6	9	7.7	0.7
Trot in hand	467	10	6	9	7.4	0.8
Free canter	467	10	5	10	7.2	0.9
Jumping technique	467	10	1	10	7.0	1.2
Temperament for jumping	467	10	1	10	7.1	1.4
Total score	467	**80**	**44**	**70**	**59.3**	**3.9**
Jumping talent	467	60	30	53	44.2	3.5
Gait talent	467	60	38	52	45.2	2.4

Figure 1, 2 and 3 show the distribution of ponies with different scores received for each of the YPT traits. On the 10 point scale, 8 was the most given score for conformation traits and walk in hand, and 7 was the most given score for trot in hand, free canter and jumping traits. The whole scale from 1 to 10 was only used for the two jumping traits.

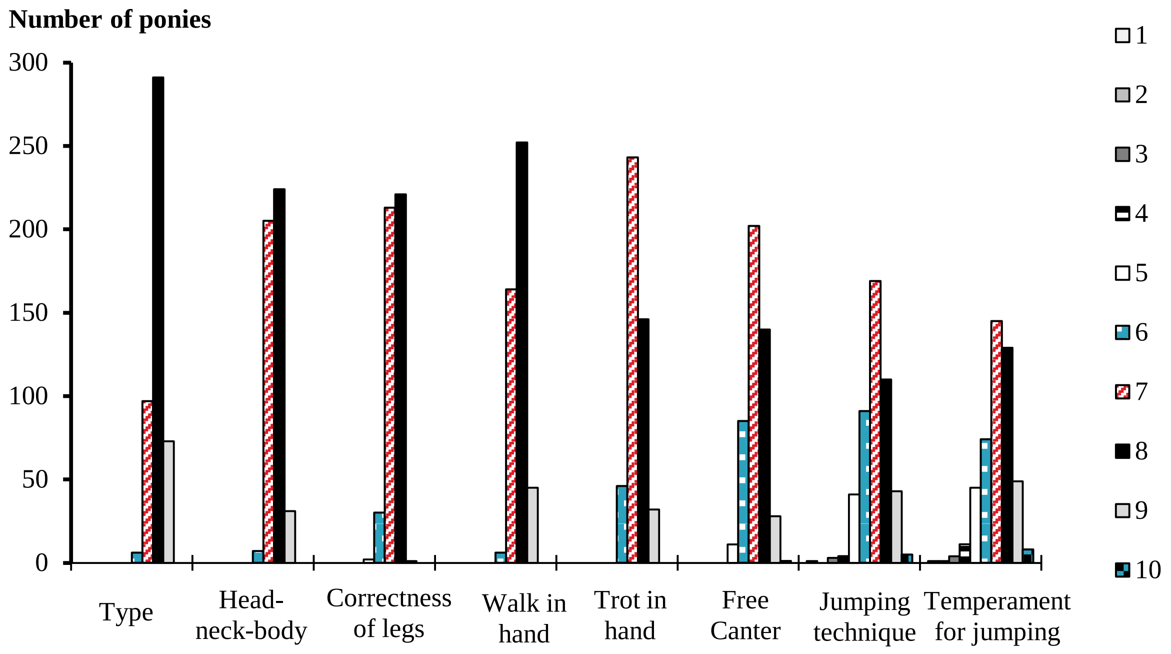

Figure 1. Distribution of ponies with different scores received for each of the eight traits assessed in Young Pony Test (YPT).

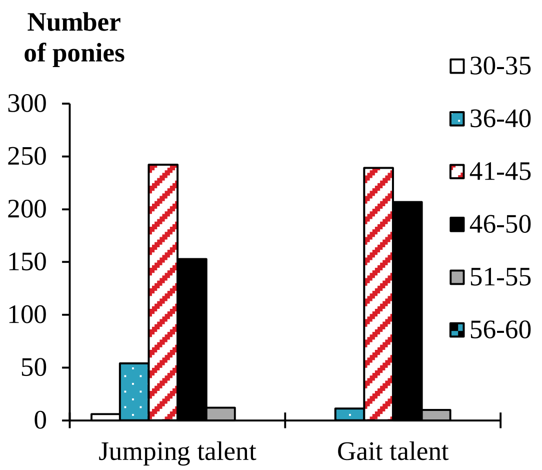

Figure 2. Distribution of ponies with different scores received for talent traits assessed in Young Pony Test (YPT).

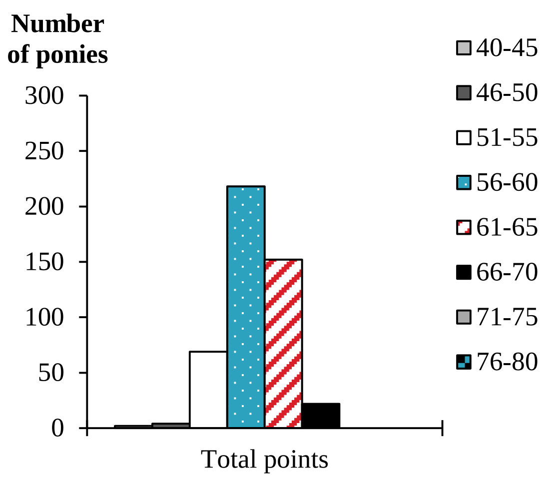

Figure 3. Distribution of ponies with different scores received for overall score in Young Pony Test (YPT) (sum of scores obtained for each trait evaluated in YPT).

4.1.2 Genetic parameters

Estimated heritabilities, genetic variances and residual variances for traits evaluated in YPT are shown in Table 7. For conformation traits, heritabilities were low to moderate with the highest being for head-neck-body and type (0.30 for both traits). Low to moderate heritabilities were also estimated for gaits with the highest being for canter (0.28), and slightly lower heritabilities were estimated for jumping traits (the highest being 0.16 for jumping technique). Gait talent and jumping talent both showed moderate and significant heritabilities (0.34 and 0.36).

Table 7. *Heritabilities (h^2), additive genetic (σ_a^2) and residual (σ_e^2) variances (standard errors as subscripts) estimated in univariate analyses for Young Pony Test (YPT) traits. Heritabilities in bold indicate significant results*

YPT trait		**$h^2_{(S.E.)}$**	**$\sigma_a^2{}_{(S.E.)}$**	**$\sigma_e^2{}_{(S.E.)}$**
Conformation	Type	**$0.30_{0.14}$**	$0.12_{0.06}$	$0.28_{0.05}$
	Head-Neck-Body	**$0.30_{0.13}$**	$0.11_{0.05}$	$0.26_{0.05}$
	Correctness of legs	$0.17_{0.13}$	$0.07_{0.05}$	$0.33_{0.05}$
Gaits	Walk in hand	$0.06_{0.10}$	$0.03_{0.04}$	$0.37_{0.05}$
	Trot in hand	**$0.24_{0.12}$**	$0.13_{0.07}$	$0.42_{0.06}$
	Free canter	**$0.28_{0.13}$**	$0.21_{0.10}$	$0.52_{0.09}$
Jumping	Jumping technique	$0.16_{0.12}$	$0.23_{0.17}$	$1.20_{0.17}$
	Temperament for jumping	$0.11_{0.11}$	$0.21_{0.20}$	$1.63_{0.22}$
Talents	Jumping talent	**$0.36_{0.13}$**	$2.00_{0.79}$	$3.58_{0.68}$
	Gait talent	**$0.34_{0.14}$**	$4.13_{1.84}$	$7.95_{1.59}$

Estimated genetic and phenotypic correlations between YPT traits are shown in Table 8. All phenotypic correlations were positive. Most genetic correlations were positive, except between correctness of legs and other conformation traits as well as with trot (-0.28 to -0.01), and between trot and jumping technique (-0.09) and walk and canter (-0.17). Excluding talent traits, the most strongly significant genetically correlated traits are type and trot in hand (1.00), and jumping technique and temperament for jumping (1.00). Strong significant genetic correlations were also estimated between head-neck body and either the jumping traits (0.62 to 0.77), type (0.81) or trot in hand (0.73). The most strongly correlated gait with jumping traits was canter (0.72 to 0.81). The talent traits showed high significant genetic correlations with most other trait: 0.67 to 0.98 for jumping talent and 0.51 to 1.00 for gait talent.

Table 8. *Genetic correlations (above the diagonal; standard errors as subscripts) and phenotypic correlations (below the diagonal) estimated in bivariate analyses for Young Pony Test (YPT) traits: type (1), head-neck-body (2), correctness of legs (3), walk in hand (4), trot in hand (5), free canter (6), jumping technique (7), temperament for jumping (8), jumping talent (A) and gait talent (B). Genetic correlations in bold indicate significant results*

YPT trait	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**A**	**B**
1		**$0.81_{0.19}$**	$-0.01_{0.43}$	$1.00_{0.53}^{*}$	**$1.00_{0.29}^{*}$**	**$0.61_{0.30}$**	$0.59_{0.40}$	$0.27_{0.39}$	**$0.67_{0.21}$**	**$1.00_{0.11}^{*}$**
2	0.53		$-0.28_{0.43}$	$1.00_{0.86}^{*}$	**$0.73_{0.29}^{*}$**	$0.57_{0.30}$	**$0.62_{0.30}$**	**$0.77_{0.35}$**	**$0.78_{0.18}$**	**$0.90_{0.13}$**
3	0.16	0.09		$1.00_{0.53}^{*}$	$-0.12_{0.43}$	$0.31_{0.46}$	$1.00_{0.68}^{*}$	$1.00_{0.69}^{*}$	$0.79_{0.40}$	$0.33_{0.34}$
4	0.14^{*}	0.08^{*}	0.08^{*}		$1.00_{1.08}^{*}$	$-0.17_{0.55}$	$0.28_{0.78}$	$0.78_{1.01}$	$1.00_{0.96}^{*}$	$1.00_{0.60}^{*}$
5	0.21^{*}	0.32^{*}	0.07	0.27^{*}		$0.12_{0.33}$	$-0.09_{0.47}$	$0.04_{0.50}$	$0.36_{0.30}$	**$0.83_{0.16}$**
6	0.19	0.25	0.06	0.22	0.37		**$0.81_{0.18}$**	**$0.72_{0.28}$**	**$0.87_{0.11}$**	**$0.51_{0.21}$**
7	0.11	0.18	0.06^{*}	0.08	0.22	0.50		**$1.00_{0.16}^{*}$**	**$0.94_{0.07}$**	**$0.60_{0.27}$**
8	0.12	0.13	0.09^{*}	0.07	0.21	0.45	0.80^{*}		**$0.98_{0.08}$**	**$0.71_{0.29}$**
A	0.44	0.46	0.30	0.16^{*}	0.33	0.69	0.84	0.84		**$0.85_{0.10}$**
B	0.62^{*}	0.59	0.40	0.51^{*}	0.64	0.66	0.36	0.33	0.71	

*Convergence criteria used was lower (norm vector of $<10^{-5}$ instead of $<10^{-7}$)

4.2 Riding Pony Quality Test

4.2.1 Descriptive statistics

Seven traits in total were scored in RPQT. Overall conformation score ranged from 31 to 43 out of 50, with the mean score being 38.5. Out of the 10 point scale, scores for gaits (including temperament for gaits) ranged from 2 to 10, and trot under rider was the trait with the lowest mean score (6.4). For the two jumping traits, mean scores were slightly higher (7.3 for both) and the given scores ranged from 3 to 10. Mean scores for all-round, jumping and gait talents ranged from 6.9 to 7.4. When adding all scores for the seven tested traits in RPQT, the range for overall score was 64-95 out of 110, and the mean was 79.6. Statistics for scores given in RPQT are shown in Table 9.

Table 9. *Number of observations (N), mean score ($\bar{x}$), standard deviation (S.D.), minimum (Min) and maximum (Max) scores for traits evaluated in Riding Pony Quality Test (RPQT) from 1990 to 2014*

RPQT trait	N	Maximum score on scale	Min	Max	$\bar{x}$	S.D.
Walk under rider	609	10	4	9	6.7	0.9
Trot under rider	609	10	4	9	6.4	0.9
Canter under rider	609	10	2	10	6.8	1.0
Temperament for gaits	609	10	3	10	6.7	0.9
Jumping technique	609	10	3	10	7.3	1.2
Temperament for jumping	609	10	3	10	7.3	1.4
Overall conformation	609	50	31	43	38.5	1.9
Total score	609	**110**	**64**	**95**	**79.6**	**5.2**
Jumping talent	609	10	4.2	9.6	7.4	0.9
Gait talent	609	10	4.6	9.3	6.9	0.7
All round talent	609	10	5.2	8.7	7.1	0.6

Figure 4, 5 and 6 show the distribution of ponies with different scores received for each of RPQT traits. On the 10 point scale, 6 and 7 were the most given scores for gait traits (including temperament for gaits), and 7 and 8 were the most given scores for jumping traits. Most of the scores on the scale from 1 to 10 were used when evaluating ponies in RPQT.

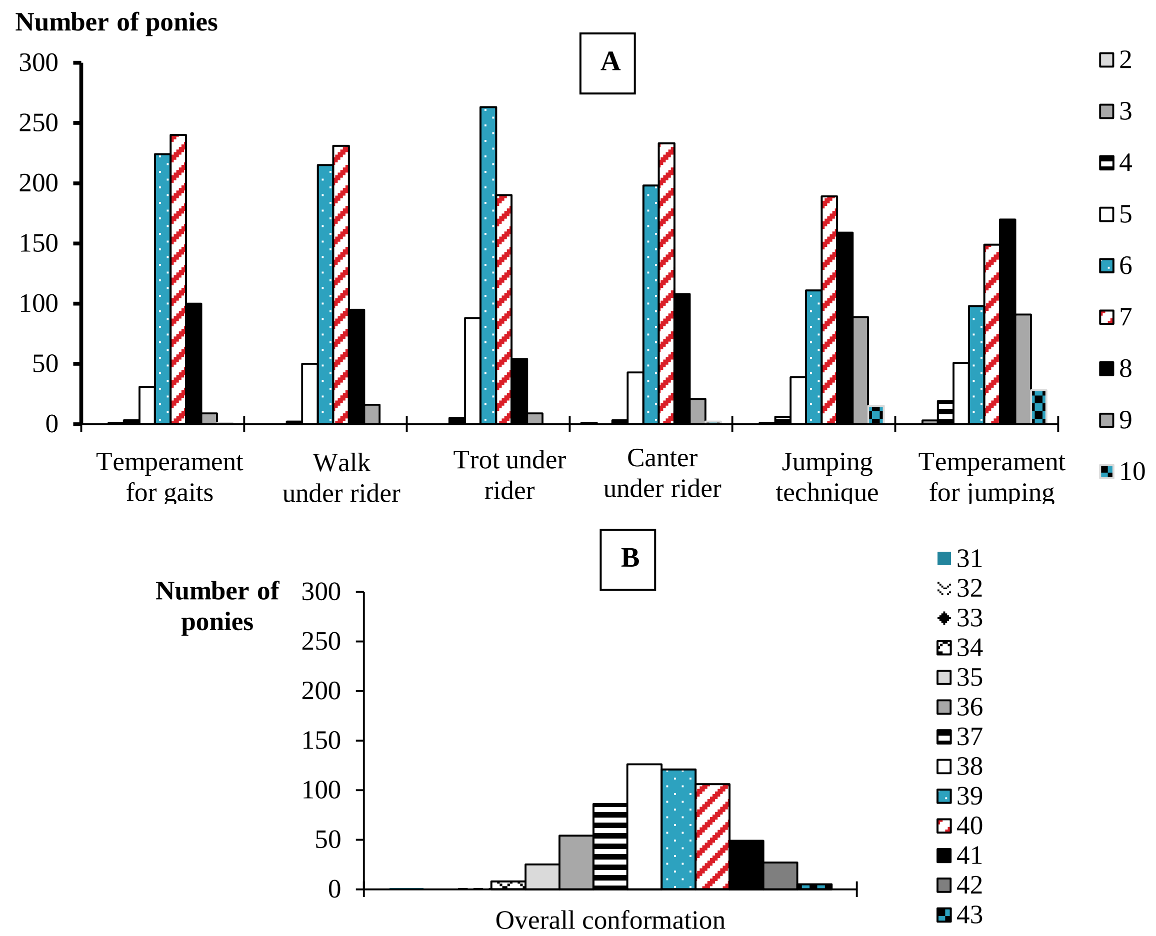

Figure 4. Distribution of ponies with different scores received for each of the seven traits assessed in Riding Pony Quality Test (RPQT). Traits scored on a 1-10 scale (A) and overall conformation score out of 50 (B).

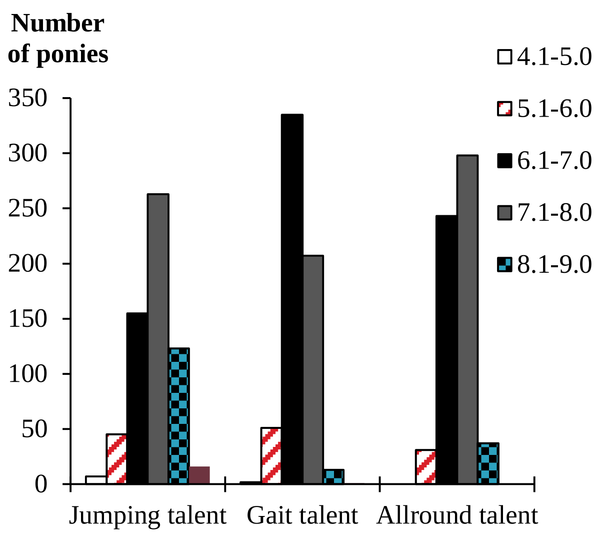

Figure 5. Distribution of ponies with different scores received for talent traits assessed in Riding Pony Quality Test (RPQT).

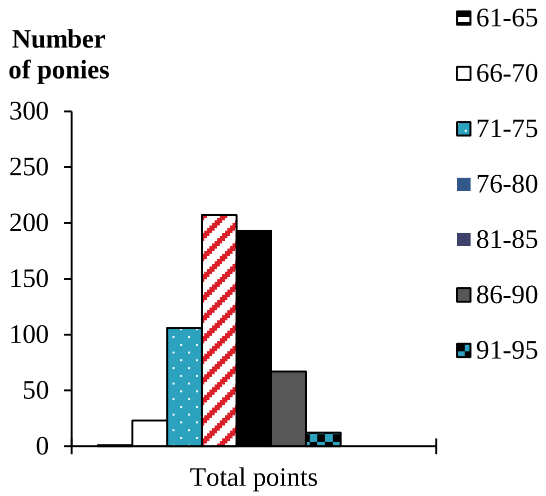

Figure 6. Distribution of ponies with different scores received for overall score in Riding Pony Quality Test (RPQT) (sum of scores obtained for each trait evaluated in RPQT).

4.2.2 Genetic parameters

Estimated heritabilities, genetic variances and residual variances for traits evaluated in RPQT are shown in Table 10. Significant and moderate to high heritabilities were estimated for all gaits (including temperament for gaits) (0.27 to 0.51), with the highest being for walk under rider. Low heritabilities were estimated for jumping traits, with the highest being for temperament for jumping (0.11 and 0.19). Estimated heritability of overall conformation score was high and significant (0.62). All-round talent and gait talent both showed quite high heritabilities, while it was lower for jumping talent (0.17 to 0.41).

Table 10. *Heritabilities (h^2), additive genetic (σ_a^2) and residual (σ_e^2) variances (standard errors as subscripts) estimated in univariate analyses for Riding Pony Quality Test (RPQT) traits. Heritabilities in bold indicate significant results*

RPQT trait		$h^2_{(S.E.)}$	$\sigma_{a\ (S.E.)}^2$	$\sigma_{e\ (S.E.)}^2$
Jumping	Jumping technique	$0.11_{0.08}$	$0.16_{0.12}$	$1.28_{0.14}$
	Temperament for jumping	$\mathbf{0.19_{0.09}}$	$0.36_{0.19}$	$1.54_{0.18}$
Gaits	Walk under rider	$\mathbf{0.51_{0.12}}$	$0.37_{0.10}$	$0.36_{0.08}$
	Trot under rider	$\mathbf{0.33_{0.11}}$	$0.24_{0.09}$	$0.49_{0.08}$
	Canter under rider	$\mathbf{0.31_{0.11}}$	$0.26_{0.10}$	$0.58_{0.09}$
	Temperament for gaits	$\mathbf{0.27_{0.11}}$	$0.18_{0.08}$	$0.50_{0.07}$
Conformation	Overall score	$\mathbf{0.62_{0.12}}$	$2.09_{0.49}$	$1.30_{0.36}$
Talents	Jumping talent	$0.17_{0.09}$	$0.14_{0.08}$	$1.69_{0.08}$
	Gait talent	$\mathbf{0.41_{0.12}}$	$0.15_{0.05}$	$0.21_{0.04}$
	All round talent	$\mathbf{0.36_{0.12}}$	$0.12_{0.04}$	$0.21_{0.04}$

Estimated genetic and phenotypic correlations between RPQT traits are shown in Table 11. All correlations were positive. Excluding talent traits, the most strongly genetically correlated traits were temperament for gaits and either overall conformation (0.84) or canter (0.81). Overall conformation showed moderate to high genetic correlations with every trait (0.29 to 0.70). The most strongly correlated gait with jumping traits was trot under rider (0.40 and 0.49). The talent traits showed high significant genetic correlations with most other trait: 0.49 to 1.00 for jumping talent, 0.58 to 0.98 for gait talent, and 0.62 to 0.94 for all round talent.

Table 11. *Genetic (above diagonal; s.e. as subscripts) and phenotypic (below diagonal) correlations estimated in bivariate analyses for Riding Pony Quality Test (RPQT) traits: jumping technique (1), temperament for jumping (2), walk (3), trot (4), and canter (5) under rider, temperament for gaits (6), overall conformation (7), jumping talent (A), gait talent (B), all round talent (C). Genetic correlations in bold indicate significant results.*

RPQT trait	1	2	3	4	5	6	7	A	B	C
1		**$0.73_{0.22}$***	$0.18_{0.31}$	$0.49_{0.35}$	$0.26_{0.37}$	**$0.63_{0.29}$**	$0.29_{0.30}$	**$0.99_{0.03}$**	$0.49_{0.28}$	**$0.81_{0.12}$**
2	0.77*		$0.26_{0.24}$	$0.40_{0.30}$	$0.33_{0.29}$	$0.54_{0.28}$	$0.39_{0.22}$	**$1.00_{0.03}$***	$0.47_{0.34}$	**$0.81_{0.10}$**
3	0.07	0.06		**$0.53_{0.18}$**	$0.27_{0.21}$	**$0.54_{0.18}$**	**$0.58_{0.13}$**	$0.32_{0.24}$	**$0.69_{0.11}$**	**$0.62_{0.14}$**
4	0.07	0.06	0.33		**$0.63_{0.18}$**	**$0.73_{0.35}$***	**$0.70_{0.17}$**	$0.55_{0.29}$	**$0.93_{0.06}$**	**$0.90_{0.13}$**
5	0.11	0.08	0.34	0.54		**$0.81_{0.13}$**	**$0.53_{0.21}$**	$0.37_{0.30}$	**$0.77_{0.10}$**	**$0.68_{0.17}$**
6	0.17	0.15	0.51	0.73*	0.69		**$0.84_{0.18}$**	**$0.67_{0.24}$**	**$0.98_{0.03}$**	**$0.94_{0.08}$**
7	0.06	0.08	0.31	0.30	0.20	0.30		**$0.49_{0.22}$**	**$0.83_{0.11}$**	**$0.75_{0.13}$**
A	0.97	0.91*	0.10	0.10	0.12	0.19	0.17		**$0.58_{0.22}$**	**$0.89_{0.06}$**
B	0.15	0.13	0.64	0.78	0.77	0.95	0.44	0.19		**$0.89_{0.08}$**
C	0.83	0.77	0.41	0.47	0.48	0.60	0.37	0.88	0.63	

*Convergence criteria used was lower (norm vector of $<10^{-5}$ instead of $<10^{-7}$)

4.3 Correlations between similar traits in YPT and RPQT

Genetic and phenotypic correlations estimated for corresponding traits between YPT and RPQT are shown in Table 12. All correlations were positive. Significant genetic correlations were estimated between overall conformation in RPQT and both type and head-neck-body in YPT (0.90 and 0.96). All gaits in YPT and their corresponding ridden gait in RPQT also showed high significant genetic correlations (0.65 to 0.90), as well as gait and jumping talent in YPT and corresponding gait and jumping talent in RPQT (0.47 and 0.74).

Table 12. *Phenotypic (r_p) and genetic (r_g) correlations (standard errors as subscripts) estimated in bivariate analyses between corresponding traits evaluated in Young Pony Test (YPT) and Riding Pony Quality Test (RPQT). Genetic correlations in bold indicate significant results*

YPT trait	RPQT trait	$r_{g\ (S.E.)}$	r_p
Type	Overall conformation	**$0.96_{0.23}$**	0.46
Head-Neck-Body	Overall conformation	**$0.90_{0.30}$**	0.24
Correctness of legs	Overall conformation	$0.37_{0.32}$	0.05
Walk in hand	Walk under rider	**$0.90_{0.24}$**	0.38
Trot in hand	Trot under rider	**$0.65_{0.28}$**	0.38
Free canter	Canter under rider	**$0.78_{0.26}$**	0.30
Jumping technique	Jumping technique	$0.41_{0.47}$	0.46
Temperament for jumping	Temperament for jumping	$0.14_{0.54}$	0.31
Jumping talent	Jumping talent	**$0.47_{0.14}$**	0.47
Gait talent	Gait talent	**$0.74_{0.23}$**	0.45

4.4 Competition

4.4.1 Descriptive statistics

Statistics on the number of ponies that started in competitions, number of ponies with wins and placings and average length of competition careers in each discipline are shown in Table 13, and statistics for the 10-log transformed competition traits are shown in Table 14. The same pony could appear in several disciplines. There were 117 ponies that had participated in all three disciplines (show jumping, dressage and eventing), of which 92 had at least one win or placing. 61% of the starts in competition were in show jumping, 28% in dressage and 11% in eventing. The percentages of ponies having at least one win or placing was 89% for ponies that started in show jumping, 81% for ponies that started in dressage, and 89% for ponies that started in eventing. However, all these results can be expected to become somewhat higher because the data includes ponies that are still competing.

The number of ponies that participated in both YPT and dressage competitions is 28, while 87 ponies participated in both YPT and show jumping competitions. The number of ponies that participated in both RPQT and dressage competitions is 136, while 211 ponies participated in both RPQT and show jumping competitions.

Table 13. *Statistics on the number of ponies starting and number of wins and placings in show jumping, dressage and eventing competitions*

YPT trait	Show jumping	Dressage	Eventing
Number of ponies at start*	1714	784	322
Average number of starts per pony (min - max)	*23.2 (1 - 331)*	*17.6 (1 - 245)*	*4.5 (1 - 63)*
Number of ponies with wins and placings	1528	633	287
Average number of wins and placings (min - max)	*13.0 (0 - 248)*	*9.5 (0 - 176)*	*3.6 (0 - 57)*
Average length (in years) of competition career (min - max)	3.0 (1 - 22)	2.7 (1 - 14)	2.1 (1 - 14)

*Ponies could have results in more than one discipline

Table 14. *Number of observations (N), mean score ($\bar{x}$), standard deviation (S.D.), minimum (Min) and maximum (Max) scores for 10-log transformed competition traits from 1993 to 2011*

Competition trait		N	Min	Max	$\bar{x}$	S.D.
Dressage	Lifetime points	784	0	3.3	1.2	0.8
	Wins+placings	784	0	2.2	0.6	0.5
	Lifetime points / Wins+placings	784	0	1.5	0.7	0.4
	Lifetime points / Number of starts	784	0	1.5	0.6	0.4
Show jumping	Lifetime points	1714	0	3.6	1.2	0.8
	Wins+placings	1714	0	2.4	0.8	0.5
	Lifetime points / Wins+placings	1714	0	1.5	0.6	0.3
	Lifetime points / Number of starts	1714	0	1.4	0.5	0.3
Eventing	Lifetime points	322	0	2.9	1.1	0.6
	Wins+placings	322	0	1.8	0.5	0.3
	Lifetime points / Wins+placings	322	0	1.3	0.7	0.3
	Lifetime points / Number of starts	322	0	1.3	0.7	0.3

Figure 7 shows the number of ponies that had at least one win or placing, compared with the number of ponies at start for easy, intermediate and advanced classes in each respective discipline. The same pony could appear in several classes. In show jumping, dressage or eventing, most ponies were starting in easy classes.

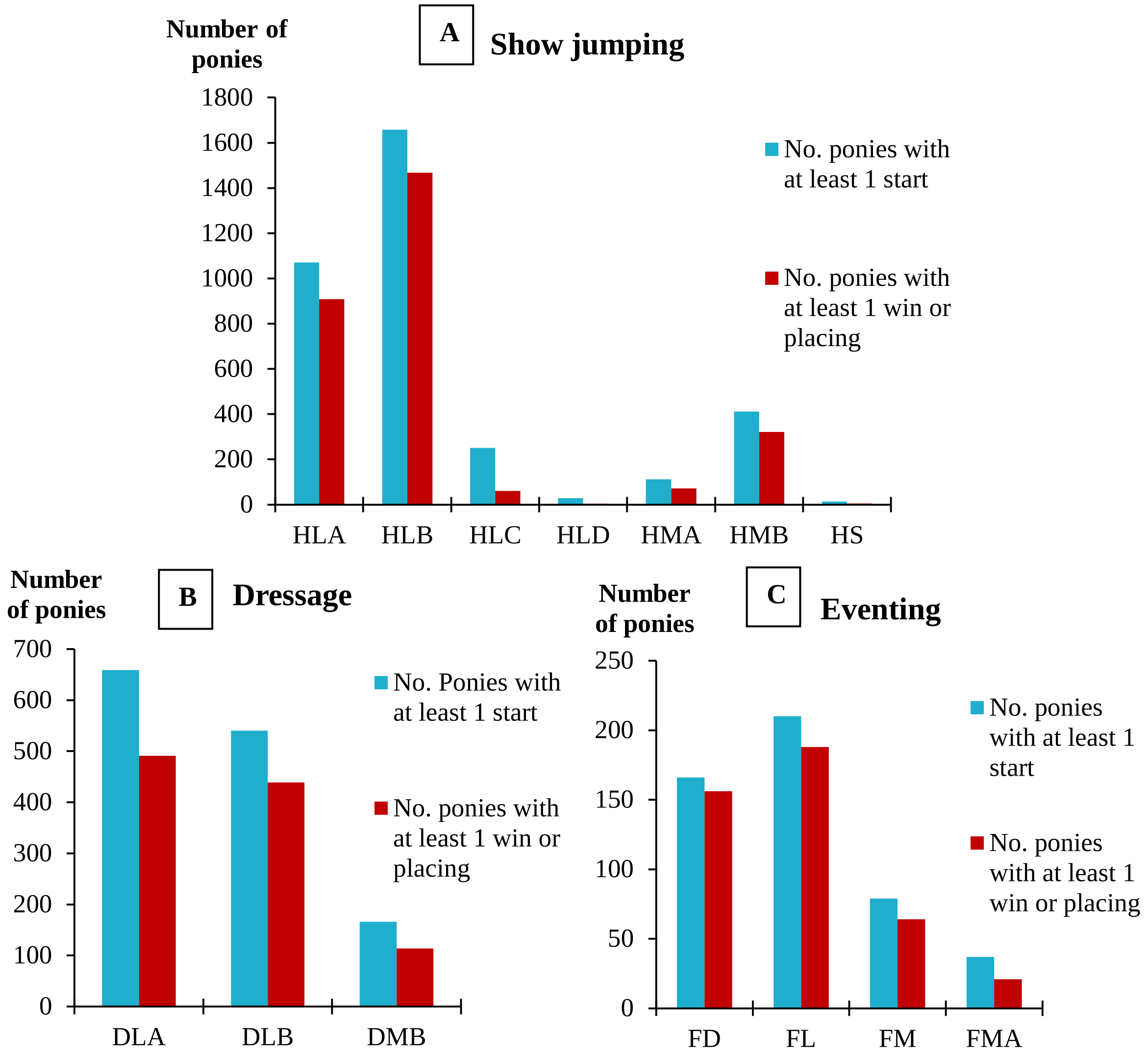

Figure 7. Number of ponies with at least one win or placing, and with at least one start in show jumping (A), dressage (B) and eventing (C) competitions. For show jumping, HLA, HLB, HLC, HLD indicate easy classes, HMA and HMB indicate intermediate classes, and HS indicates advanced class. For dressage, DLA and DLB indicate easy classes, and DMB indicates intermediate class. For eventing, FD indicates beginner class, FL indicates easy class, and FM and FMA indicate intermediate classes.

4.4.2 Genetic parameters

Estimated heritabilities, genetic variances and residual variances for competition traits are shown in Table 15. Heritabilities were low to moderate and significant for show jumping traits (0.11 to 0.24), lower for dressage traits (0.04 to 0.09) and not significant for eventing traits.

Given the heritabilities and variances, four competition traits were chosen to be used for genetic correlation estimations: lifetime points in show jumping and dressage, and the ratio lifetime points/number of starts in show jumping and dressage. Results from eventing competitions were not included in further analyses because there were too few ponies competing in eventing, which gave not significant estimated heritabilities.

Table 15. *Heritabilities (h^2), additive genetic (σ_a^2) and residual (σ_e^2) variances (standard errors as subscripts) estimated in univariate analyses for competition traits transformed with 10-log. Heritabilities in bold indicate significant results*

Competition trait		$h^2_{(S.E.)}$	$\sigma_{a(S.E.)}^2$	$\sigma_{e(S.E.)}^2$
Dressage	Lifetime points	$0.08_{0.06}$	$0.05_{0.04}$	$0.57_{0.04}$
	Wins+placings	$0.09_{0.06}$	$0.02_{0.02}$	$0.23_{0.02}$
	Lifetime points / Wins+placings	$0.04_{0.05}$	$0.01_{0.01}$	$0.11_{0.01}$
	Lifetime points / Number of starts	$0.07_{0.06}$	$0.01_{0.00}$	$0.07_{0.01}$
Show jumping	Lifetime points	$\mathbf{0.24_{0.06}}$	$0.14_{0.03}$	$0.44_{0.03}$
	Wins+placings	$\mathbf{0.24_{0.06}}$	$0.07_{0.02}$	$0.21_{0.01}$
	Lifetime points / Wins+placings	$\mathbf{0.16_{0.05}}$	$0.01_{0.00}$	$0.05_{0.00}$
	Lifetime points / Number of starts	$\mathbf{0.11_{0.04}}$	$0.01_{0.00}$	$0.04_{0.00}$
Eventing	Lifetime points	$0.00_{0.10}$	$0.00_{0.03}$	$0.31_{0.04}$
	Wins+placings	$0.01_{0.10}$	$0.00_{0.01}$	$0.09_{0.01}$
	Lifetime points / Wins+placings	$0.00_{0.13}$	$0.00_{0.01}$	$0.09_{0.01}$
	Lifetime points / Number of starts	$0.00_{0.12}$	$0.00_{0.01}$	$0.07_{0.01}$

4.5 Correlations between competition and tests for young ponies

4.5.1 Correlations between competition and YPT traits

Genetic and phenotypic correlations estimated between traits evaluated in YPT and jumping and dressage competition traits are shown in Table 16 and 17. Significant positive genetic correlations were estimated between wins and placings in show jumping and both YPT traits trot and gait talent, as well as between lifetime points in show jumping and jumping talent in YPT (0.50 to 0.57).

Table 16. *Genetic (r_g) and phenotypic (r_p) correlations (standard errors as subscripts) estimated in bivariate analyses between Young Pony Test (YPT) traits and lifetime points in show jumping and dressage competitions. Genetic correlations in bold indicate significant results*

	Lifetime points jumping		**Lifetime points dressage**	
YPT trait	$r_{g\ (S.E.)}$	r_p	$r_{g\ (S.E.)}$	r_p
Type	$0.41_{0.27}$	0.13	$1.00_{0.59}^{*}$	0.08^{*}
Head-Neck-Body	$0.48_{0.29}$	-0.02	$0.86_{0.51}$	-0.16
Correctness of legs	$0.38_{0.37}$	0.11	$0.25_{0.63}$	0.07
Walk in hand	$0.47_{0.55}$	-0.24	$1.00_{1.24}^{*}$	0.19^{*}
Trot in hand	$\mathbf{0.59_{0.27}}$	0.05	$1.00_{0.60}^{*}$	-0.03^{*}
Free canter	$0.39_{0.27}$	0.08	$0.91_{0.49}$	0.12
Jumping technique	$0.53_{0.35}$	0.14	$0.65_{0.63}$	0.19
Temperament for jumping	$0.62_{0.45}$	0.03	$0.60_{0.73}$	0.17
Jumping talent	$\mathbf{0.50_{0.24}}$	0.12	$0.87_{0.55}$	0.20
Gait talent	$\mathbf{0.58_{0.22}}$	0.06	$1.00_{0.54}^{*}$	0.09^{*}

*Convergence criteria used was lower (norm vector of $<10^{-5}$ instead of $<10^{-7}$)

Table 17. *Genetic (r_g) and phenotypic (r_p) correlations (standard errors as subscripts) estimated in bivariate analyses between Young Pony Test (YPT) traits and the ratio (lifetime points)/(number of starts) in show jumping and dressage competitions*

	Ratio points/starts jumping		**Ratio points/starts dressage**	
YPT trait	$r_{g\ (S.E.)}$	r_p	$r_{g\ (S.E.)}$	r_p
Type	$0.50_{0.34}$	0.14	$1.00_{0.64}$*	0.13*
Head-Neck-Body	$0.62_{0.35}$	-0.01	$0.59_{0.59}$	-0.23
Correctness of legs	$0.30_{0.47}$	0.09	$0.56_{0.63}$	0.20
Walk in hand	$0.42_{0.70}$	-0.30	$1.00_{1.00}$*	0.15*
Trot in hand	$0.57_{0.37}$	-0.10	$1.00_{0.60}$*	0.10*
Free canter	$0.30_{0.37}$	0.00	$0.74_{0.53}$	0.04
Jumping technique	$0.32_{0.47}$	0.07	$0.59_{0.67}$	0.20
Temperament for jumping	$0.33_{0.54}$	0.02	$0.43_{0.75}$	0.20
Jumping talent	$0.74_{0.59}$	0.22	$0.41_{0.32}$	0.06
Gait talent	$0.58_{0.30}$	-0.06	$1.00_{0.55}$*	0.14*

*Convergence criteria used was lower (norm vector of $<10^{-5}$ instead of $<10^{-7}$)

4.5.2 Correlations between competition and RPQT traits

Genetic and phenotypic correlations estimated between traits evaluated in RPQT and competition traits are shown in Table 18 and 19. Several high and significant genetic correlations were estimated between RPQT traits and competition traits, with the highest being between lifetime points in show jumping and jumping talent (0.98) and between ridden canter and both wins and placings in dressage, and lifetime points in dressage (0.96).

Table 18. *Genetic (r_g) and phenotypic (r_p) correlations (standard errors as subscripts) estimated in bivariate analyses between RPQT traits and lifetime points in show jumping and dressage competitions. Genetic correlations in bold indicate significant results*

	Lifetime points jumping		**Lifetime points dressage**	
RPQT trait	$r_{g\ (S.E.)}$	r_p	$r_{g\ (S.E.)}$	r_p
Jumping technique	$\mathbf{0.89_{0.25}}$	0.09	$0.62_{0.56}$	0.09
Temperament for jumping	$0.49_{0.46}$	0.16	$0.15_{0.47}$	0.14
Walk under rider	$-0.11_{0.21}$	-0.11	$0.16_{0.35}$	0.05
Trot under rider	$\mathbf{0.54_{0.21}}$	0.08	$0.46_{0.41}$	0.26
Canter under rider	$0.05_{0.26}$	-0.07	$\mathbf{0.96_{0.23}}$	0.23
Temperament for gaits	$0.43_{0.51}$	0.32	$0.74_{0.38}$	0.24
Overall conformation	$0.09_{0.36}$	0.20	$0.55_{0.38}$	0.27
Jumping talent	$\mathbf{0.98_{0.44}}$	0.18	$0.53_{0.48}$	0.14
Gait talent	$0.41_{0.41}$	0.32	$\mathbf{0.74_{0.31}}$	0.27
All round talent	$\mathbf{0.80_{0.35}}$	0.28	$\mathbf{0.73_{0.33}}$	0.24

Table 19. *Genetic (r_g) and phenotypic (r_p) correlations (standard errors as subscripts) estimated in bivariate analyses between RPQT traits and the ratio (lifetime points)/(number of starts) in show jumping and dressage competitions. Genetic correlations in bold indicate significant results*

	Ratio points/starts jumping		**Ratio points/starts dressage**	
RPQT trait	$r_{g\ (S.E.)}$	r_p	$r_{g\ (S.E.)}$	r_p
Jumping technique	$\mathbf{0.93_{0.29}}$	-0.00	$1.00_{0.50}$*	0.13*
Temperament for jumping	$\mathbf{0.64_{0.30}}$	-0.04	$\mathbf{0.74_{0.23}}$	0.05
Walk under rider	$-0.17_{0.27}$	-0.17	$-0.13_{0.37}$	0.09
Trot under rider	$\mathbf{0.59_{0.25}}$	0.05	$0.35_{0.44}$	0.28
Canter under rider	$0.18_{0.32}$	-0.06	$\mathbf{0.80_{0.33}}$	0.26
Temperament for gaits	$\mathbf{0.58_{0.27}}$	-0.02	$0.39_{0.24}$	-0.03
Overall conformation	$-0.11_{0.26}$	0.01	$-0.02_{0.20}$	0.03
Jumping talent	$\mathbf{0.81_{0.28}}$	-0.01	$\mathbf{0.82_{0.23}}$	0.08
Gait talent	$0.39_{0.26}$	-0.05	$0.27_{0.22}$	-0.04
All round talent	$\mathbf{0.70_{0.24}}$	-0.04	$\mathbf{0.63_{0.20}}$	0.03

*Convergence criteria used was lower (norm vector of $<10^{-5}$ instead of $<10^{-7}$)

4.6 Estimated Breeding Values (EBV)

Ranking for stallions for some YPT, RPQT, and competition traits according to their EBVs are shown in **appendix 1**. Breeding values for stallions having at least 10 tested or competed offspring are presented. There were 16 stallions with more than 10 offspring tested in YPT, 15 stallions for RPQT, 56 stallions for show jumping competition, 21 stallions for dressage competitions, and 3 stallions for eventing competitions; however, only the 10 top stallions are presented.

Since some offspring had both competed and been tested, breeding values were estimated for 65 different stallions in total that were the progeny of 50 different sires and 60 different dams. Their birth years are shown in Table 20. 94% of the stallions were born before 2000.

Table 20. *Distribution of birth years for stallions having at least ten tested or competed offspring*

Birth years	1964-1965	1966-1970	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2004
Number of stallions	1	4	17	4	14	10	8	2	4

Average EBVs for ponies with show jumping and dressage competition results by birth years, from 1974 to 2006, are presented in Figure 8. Birth years from 1970 to 1973 are not included in the figure because the low number of ponies born these years would not give accurate results. The genetic trend for show jumping and dressage is rather low but there still has been an increase in the EBVs since 1986. Between 1985 and 2005, there was an increase in genetic progress of 0.009 genetic Standard Deviation (SD) per year for dressage and 0.016 genetic SD per year for show jumping.

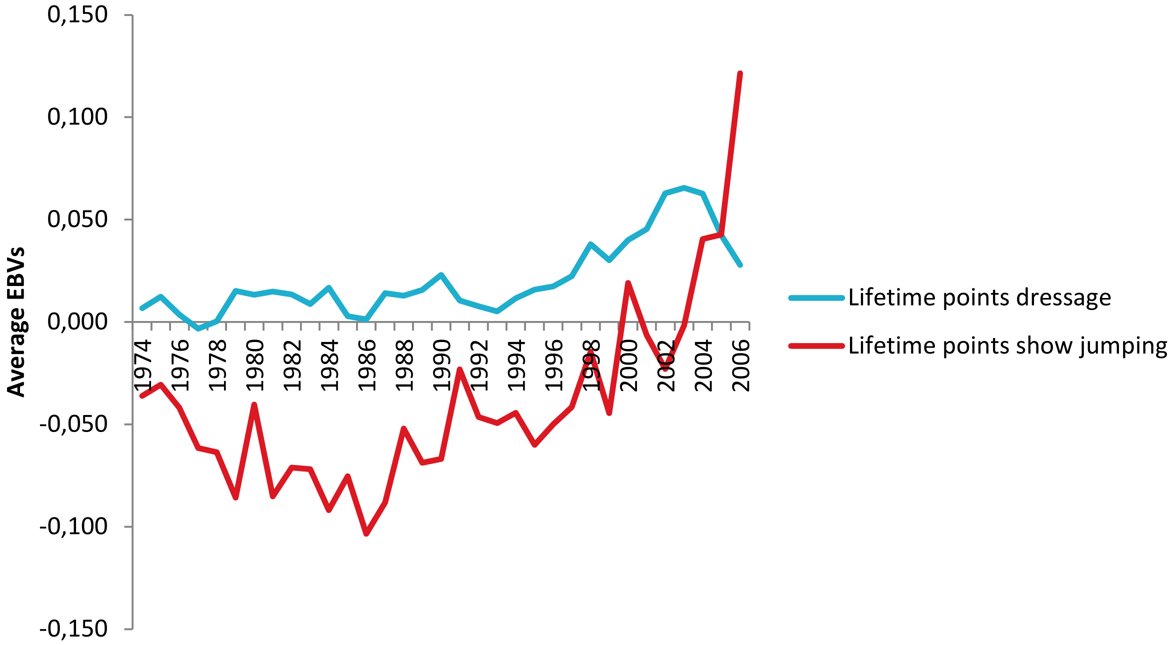

Figure 8. Average Estimated Breeding Values (EBVs) for lifetime point in dressage and lifetime points in show jumping competitions for birth years 1974 to 2006.

5. Discussion

5.1 The New Forest pony breeding objectives

Breeding objectives specifies that New Forest ponies should be suitable for all equine sport disciplines (SNF, 2010). Nonetheless, no precise performance traits are stated. For sport horse breeding, all traits that breeders wish to improve with breeding should be measureable and defined in the breeding objectives in order to carry out a successful breeding program and obtain maximum genetic response (Koenen et al., 2004). Since SNF shows interest in breeding for performance, the competition traits evaluated in this study (performance in dressage, show jumping and eventing) should therefore be stated more precisely in the New Forest pony breeding objectives. This would enable to consider in details all traits needed to select for to genetically improve the New Forest for performance in these disciplines. The testing schemes for New Forest ponies (YPT, RPQT and competitions) will then be used to provide breeders and owners with accurate and understandable tests results on the traits of interest.

The New Forest breeding objectives also state durability. This trait is important to consider in horse and pony breeding since most breeders and owners are aiming to respect animal welfare by breeding sound and healthy ponies that are durable. Braam (2011) showed that breeding values estimated for the trait "number of years in competition" in each discipline was a good indicator of durability for Swedish Warmblood horses. Further studies could be carried out to analyse this trait in the New Forest pony population and see if it could be used as a complement to other breeding values for performance. Lifetime points is a trait that partly reflects durability, but other durability traits could be analysed as well, such as "number of starts", to make a comparison.

5.2 Genetic parameters

5.2.1 Young horse and pony performance tests

Estimated heritabilities for dressage-related traits in both YPT and RPQT (gaits, temperament for gaits in RPQT) were generally moderate in this study, and they were low for jumping-related traits, with few exceptions. For Connemara ponies, Noréus, 2014 estimated similar heritabilities for gaits but higher for jumping traits, which seemed to be in accordance with estimated heritabilities for horses (Luehrs-Behnke et al., 2002; Ducro et al., 2007; Viklund et al., 2008; Becker et al., 2011). In this study, the genetic correlations within and between performance tests were all positive and generally high between jumping-related traits and dressage-related traits, except between walk in hand and free canter in YPT (-0.17). For horses, many studies seemed to agree that canter is the gait that is the most genetically correlated to jumping traits, while walk and trot showed weak correlations (Thorén Hellsten et al., 2006). This is consistent with what was found for ponies in this study between free canter and jumping traits in YPT (0.72 and 0.81), and by Noréus (2014) between canter under rider and jumping traits in RPQT (0.69 and 0.87). However, for Connemara ponies, there was a disagreement for free canter in YPT, which was negatively correlated with both jumping traits (-0.18 and -0.34)

(Noréus, 2014) and in this study trot in hand in YPT was the most strongly correlated gait with jumping traits, but these correlation showed rather high standard errors and might not be reliable.

In this study, significant moderate heritabilities were estimated for talent traits in YPT (0.34 and 0.36) and RPQT (0.36 and 0.41), with an exception for jumping talent in RPQT that showed a low heritability (0.17), however not significant. Genetic correlations between talent traits and other YPT and RPQT traits were generally significant and strong: from 0.51 to 1.00 in YPT and from 0.49 to 1.00 for RPQT. Correlations were also high between the corresponding traits between the two tests (0.47 and 0.74), and between talent traits in both tests and either show jumping competition traits (0.41 to 0.98) or dressage competition traits (0.41 to 1.00), except between gait and jumping talent and the dressage trait lifetime points/number of starts (0.27 and 0.39), which were however not significant. These results suggest that talent traits evaluated in young pony performance tests might be good indicators of performance in competition.

Conformation was shown to be the most important non-performance trait recorded by breeding organisations in several countries (Koenen and Aldridge, 2002). Recording conformation traits in tests for young horses can be a good predictor of longevity in competition (Wallin et al. 2001; Jönsson et al., 2014a), which is a trait specified in the New Forest pony breeding objectives. Conformation is defined differently across countries and breeding organisations. In some cases, like in this study, conformation traits are evaluated individually according to the breeding objectives or as an overall score (Aminder, 2002; Wallin et al., 2003; Viklund et al., 2008; Jönsson et al., 2014b; Noréus, 2014), and sometimes a linear scale is used (Van Bergen & Arendonk, 1993; Koenen et al., 1995; Rustin et al., 2009). Linear scoring gives a description of conformation traits on a continuous scale from one extreme to another. It was found to be more objective than the regular trait recordings, which could result in higher heritabilities and provide faster genetic progress (Hedlund, 2012). For New Forest ponies, it could be a good addition to current traits scored in YPT and RPQT to implement linear description related to breed standards stated in the breeding objectives.

In this study, conformation traits in YPT showed moderate heritabilities, except for correctness of legs (0.17); while the heritability for overall conformation was high in RPQT (0.62). Comparable heritabilities were estimated in Connemara ponies (0.15 and 0.50) (Noréus, 2014) and Swedish Warmblood horses (0.24 to 0.58) (Viklund et al., 2008), with the same exception for correctness of legs (0.04 and 0.08, respectively). This is also similar to estimated heritabilities for conformation traits in exhibition and conformation shows by Aminder (2002) for New Forest (0.15 to 0.33) and Connemara ponies (0.05 to 0.25). Estimated heritabilities for overall conformation varied more between studies: 0.18 for Connemara ponies (Noréus, 2014), 0.56 for New Forest and 0.26 for Connemara ponies (Aminder (2002)), 0.55 (Viklund et al., 2008) and 0.33 (Wallin et al., 2003) for Swedish Warmblood horses. In this study, only the overall conformation score was available for RPQT. Considering the important differences for this trait between studies, it could be interesting to record all the sub-scores in the future for more reliable genetic analyses and maybe for more direct breeding for specific conformation traits. In this study, genetic correlation between gaits and conformation traits within young pony tests were moderate to high, except between trot in hand and correctness of legs in YPT (-0.12). Most other studies on horses and ponies showed moderate to high genetic correlation as well, except between correctness of legs and gait traits for horse breeds where genetic correlations were low (Ducro et al., 2007; Viklund et al., 2008; Schöpke and Swalve, 2012; Noréus, 2014). Genetic correlations between jumping and conformation traits varied more between studies but were in general lower.

5.2.2 Competitions

In this study, heritabilities for jumping competition traits (0.11 to 0.24) were generally higher than for dressage traits (0.04 to 0.09). An explanation can be that show jumping results are less dependent on the rider and more on the horses' own talent than dressage results (Kearsley et al., 2008). Heritabilities for eventing were not significant because too few ponies competed in this discipline. For Connemara ponies, Noréus (2014) estimated higher heritabilities for lifetime points in the three disciplines (0.22 to 0.35), with the highest also being for show jumping and the lowest for eventing. The same tendency was reported in horse breeds (Wallin et al., 2003; Ducro et al., 2007; Viklund et al., 2010). More generally, competition traits often show lower heritabilities than young horse or pony performance test traits because the horses competing are older and have been more affected by environmental factors such as rider influence and training (Viklund, 2010). For this study, several competition traits were used in the analyses, but the one found to be the more relevant in each discipline was lifetime points because it had a higher estimated heritability and higher genetic variance.

Concerning genetic correlations, conformation has been shown to be more correlated to dressage performance in horse breeds, but it seems also important for show jumpers (Wallin et al., 2003; Ducro et al., 2007; Viklund et al., 2010). Similar results were found in this study with moderate to high genetic correlations between conformation traits in YPT and all dressage and show jumping competition traits (0.25 to 1.00). On the other hand, overall conformation in RPQT showed low negative to low positive genetic correlations with show jumping traits (-0.11 and 0.09) and with the dressage trait lifetime points/number of starts (-0.02). For Connemara ponies, all conformation traits were found to be negatively correlated with show jumping and dressage traits, except for correctness of legs (Noréus, 2014). However, in this study and the one by Noréus (2014) genetic correlations for conformation traits showed rather high standard errors, so the estimates are not reliable. Also in this study, only 104 ponies have participated in both YPT and competitions and 285 ponies have participated in both RPQT and competitions. These numbers might not be high enough to give reliable genetic correlations.

Genetic correlations between young horse or pony test traits and competition traits differed somewhat between studies. In this study, gait traits were genetically correlated with dressage traits, and jumping traits were correlated with show jumping, with a few exceptions. Genetic correlations between gait traits in YPT and RPQT and show jumping traits were lower but positive, except for walk under rider in RPQT (-0.17). For Connemara ponies, Noréus (2014) found moderate to high correlation between gaits in RPQT and dressage competition, however most other genetic correlations either between gaits in YPT and dressage or gaits in YPT and RPQT and show jumping were negative. For horses on the other hand, genetic correlations between gaits in young horse tests and dressage, as well as between jumping traits in young horse tests and show jumping were high and positive, and canter was the only gait significantly and positively correlated with show jumping (Wallin et al., 2003; Ducro et al., 2007; Viklund et al., 2010). The mainly positive genetic correlations between performance test traits and competition traits in this study confirm that these traits are comparable and controlled for a large part by the same genes, as it is the case for horses. However, most genetic correlations between tests for young ponies and competitions were not significant because too few ponies participated.

5.3 Perspectives

Genetic evaluation (estimation of breeding values) for traits can be based on performance testing of young ponies and competition performance for older ponies. Moreover, the higher the heritability of a trait, the more accurate will the breeding value be for this trait. The heritabilities and genetic correlations presented in this study were however not always high or significant because the New Forest population in Sweden is relatively small and not all ponies are tested in performance tests before starting a competition career. Competition data is bigger than young pony test data and is a direct measure of pony performances, but it can only be analysed relatively late in life, so performance testing enables to analyse results for younger ponies. The number of registered New Forest foals in Sweden was between 106 and 124 in the years 2009-2011 (Lundqvist 2014) and 16 to 28 ponies participated in YPT three years later (2012-2013), as well as 16 ponies in RPQT 4 years later (in 2013 and in 2014). By suggesting that about 10% of the registered foals are lost (exported, dead, etc.), the proportion of participating ponies varied from about 21% to about 30% in YPT between 2012-2014, and from about 14% to about 16% in RPQT in 2013 and 2014, respectively. The proportion of young ponies tested is quite low but comparable to the proportion of young horse tested per year for several European horse breeds (13% to 45%) (Thorén Hellsten et al., 2006). In order to have more accurate results and faster genetic progress in the future, SNF should encourage breeders and owners to show their ponies in YPT and RPQT to have a more extensive performance testing of young ponies. In this study, out of the 65 stallions that had at least 10 tested or competed offspring, 94% were born before 2000. Consequently, it appears that it takes a rather long time before they have enough tested or competed offspring. Having more young ponies tested would enable genetic evaluation for the breed in the future. However, the number of registered foals has halved between 2012 and 2013 (Lundqvist 2014), so it can be quite challenging for the breed association to increase the number of participating ponies if the number continue to decrease in the coming years.

Ranking of the top ten stallions having at least 10 tested or competed offspring according to their EBVs showed that many stallions appear in several rankings for different traits: for example the YPT traits jumping talent and gait talent have the same first three stallions. This can be explained because only few stallions had over 10 offspring tested. Nonetheless, it was found that the 65 stallions in total having at least 10 tested or competed offspring were the progeny of 50 different sires and 60 different dams suggesting that they were not very closely related.

Some aspects of performance tests for young ponies could also be modified in order to have more relevant results. Scoring in the tests is made on a 10 point scale for most traits; however the scale is poorly used. The entire scale from 1 to 10 was only used for the jumping traits in YPT and the other traits were scored from 5 to 10 (5 to 9 for conformation traits) in YPT and mostly from 3 to 10 in RPQT. Using the entire scale for all traits would enable to select more easily the best ponies.

6. Conclusion

In this study, genetic parameter estimates for YPT, RPQT and competition traits were high enough for being used in genetic evaluation of the New Forest pony population in Sweden, and the pedigree data was of good quality. These are prerequisite for the estimation of breeding values for conformation and performance traits of the breed. However, the New Forest population is rather small compared with horse breeds for which genetic evaluations are carried out nowadays. Consequently, breeding values would even be more reliable if more ponies were tested or competed. The Swedish New Forest association should encourage breeders and owners to participate even more in YPT and RPQT, but also in competitions in order to obtain sufficient amount of data in the future, which would enable faster genetic progress for the breed.

References

Articles

Aminder, E. 2002. Genetic parameters for conformation traits in the Swedish Connemara and New Forest ponies (Genetisk analys av premierings- och utställningsresultat hos connemara och new forest). *Master Thesis 228*, Swedish University of Agricultural Sciences, Uppsala.

Árnason, T. 1987. Contribution of various factors to genetic evaluation of stallions. *Livestock Production Science*, 16: 407-419.

Árnason, T., Van Vleck, L.D. 2000. Genetic Improvement of the Horse. In: Bowling A. T. and Ruvinsky, A. *The Genetics of the Horse*. CAB International, Oxon, UK, 473-497.

Bølling D. 2011. Description competition index (Beskrivelse konkurrenceindeks). Word-document received 11 September 2012. 6pp.

Becker, A.C., Stock, K.F. and Distl, O. 2011. Genetic correlations between free movement and movement under rider in performance tests of German Warmblood horses. *Livestock Science*, 142, 245-252.

Bruns, E., Ricard, A. and Koenen, E. 2004. Interstallion – on the way to an international genetic evaluation of sport horses. *55th Annual Meeting of the European Association for Animal Production, Bled, Slovenia, 5–9 September*. Available at:
http://www.eaap.org/Previous_Annual_Meetings/2004Bled/papers/HG5.2_Bruns.pdf [2015-05-15].

Ducro, BJ, Koenen, EPC, van Tartwijk, JMFM and Bovenhuis, H. 2007. Genetic relations of movement and free-jumping traits with dressage and show-jumping performance in competition of Dutch Warm Blood Horses. *Livestock Science*, 107, 227-234.

Hedlund, S. 2012. A comparison between linear and traditional scoring systems in horses (En jämförelse mellan linjära och traditionella bedömningssystem hos hästar). *Bachelor Thesis 377*, Swedish University of Agricultural Sciences, Uppsala.

Huizinga, H. A. and van der Meij, G. J. 1989. Estimated parameters of performance in jumping and dressage competition of the Dutch Warmblood horse. *Livestock Production Science*, 21, 333-345.

Huizinga, H.A.; Korver, S. and van der Meij, G.J.W. 1991. Stationary performance testing of stallions from the Dutch Warmblood riding horse population. 2. Estimated heritabilities of and correlations between successive judgements of performance traits. *Livestock Production Science*, 27, 245-254.

Jensen, J., Mäntysaari, E.A., Madsen, P. and Thompson, R. 1997. Residual maximum likelihood estimation of (co)variance components in multitrait mixed linear models using average information. *Journal of theIndian Society of Agricultural Statistics*, 49, 215-236.

Jönsson, L. 2013. Orthopaedic Health, Conformation and Longevity in Riding Horses – a genotypic and phenotypic study. *Doctoral Thesis*. Swedish University of Agricultural Science. Department of Animal Breeding and Genetics. Uppsala. ISSN 1652-6880. Available at:
http://pub.epsilon.slu.se/10756/1/Jonsson_l_130820.pdf [2015-05-22].

Jönsson, L., Egenvall, A., Roepstorff, L., Näsholm, A., Dalin, G. and Philipsson, J. 2014a. Association of health status and conformation with longevity and lifetime competition performance in young Swedish warmblood riding horses: 8,238 cases (1983-2005). *Journal of the American Veterinary Medical Association*, 244, 1449-1461.

Jönsson, L., Näsholm, A., Roepstorff, L., Egenvall, A., Dalin, G. and Philipsson, J. 2014b. Conformation traits and their genetic and phenotypic associations with health status in young Swedish warmblood riding horses. *Livestock Science*, 163, 12-25.

Kearsley C.G.S., Woolliams J.A., Coffey M.P. and Brotherstone S. 2008. Use of competition data for genetic evaluations of eventing horses in Britain: Analysis of the dressage, showjumping, and cross country phases of eventing competition. *Livestock Science*, 118, 72-81.

Koenen E.P.C., Van Veldhuizen A.E. and Brascamp E.W. 1995. Genetic parameters of linear scored conformation traits and their relation to dressage and show-jumping performance in the Dutch Warmblood riding horse population. *Livestock Production Science*, 43, 85-94.

Koenen, E.P.C. and Aldridge, L.I. 2002. Testing and genetic evaluation of sport horses in an international perspective. 7th World Congress Applied to Livestock Production, Montpellier. Available at: http://www.biw.kuleuven.be/Genlog/livgen/research/interstallion/publications/wcgalp-paper.pdf [2015-04-13].

Koenen, E.P.C., Aldridge, L.I. and Philipsson, J. 2004. An overview of breeding objectives for warmblood sport horses. *Livestock Production Science*, 88, 77–84.

Luehrs-Behnke, H., Roehe, R. and Kalm, E. 2002. Genetic associations among traits of the new integrated breeding evaluation method used for selection of German warmblood horses. *Veterinarija ir Zootechnika*, 18 (40), 90-93.

Lundqvist, T. 2014. Horses and breeders in Sweden! (Hästar och uppfödare i Sverige! En sammanställning av nyckeltal för svensk hästuppfödning för åren 2009 – 2013). Swedish Horse Council Foundation (HNS) Breeding report. Available at:
http://www.atl.nu/sites/atl.nu/files/Avelsrapport_2013_140707.pdf [2015-04-13].

MacCluer, J.W., Boyce, A.J., Dyke, B., Weitkamp, L.R., Pfenning, D.W. and Parsons, C.J. 1983. Inbreeding and pedigree structure in Standardbred horses. *Journal of heredity*, 74, 394-399.

Noréus, S. 2014. Genetisk analys av prestationsdata hos connemaraponnyn. *Examensarbete 452*. Sveriges Lantbruksuniversitet, Uppsala.

Ray, B.A. 2012. Genetic analysis of eventing data in the Swedish Warmblood population. *Examensarbete 362*. Sveriges Lantbruksuniversitet, Uppsala.

Ricard A. and Chanu I. 2001. Genetic parameters of eventing horse competition in France. *Genetics, Selection, Evolution*, 33, 175-190.

Ricard, A. 2004. Heritability of jumping ability and height of pony breeds in France. *Livestock Production Science*, 89, 243-251

Ricard, A., Bruns, E., and Cunningham, E.P. 2000. Genetics of Performance Traits. In: Bowling A. T. and Ruvinsky, A. *The Genetics of the Horse*. CAB International, Oxon, UK, 411-438.

Rustin M., Janssens S., Buys N. and Gengler N. 2009. Multi-trait animal model estimation of genetic parameters for linear type and gait traits in the Belgian warmblood horse. *Journal of Animal Breeding and Genetics*, 126, 378-386.

Samoré, A..B., Pagnacco, G. and Miglior F. 1997. Genetic parameters and breeding values for linear type traits in the Haflinger horse. *Livestock Production Science*, 52, 105-111.

Schöpke, K. and Swalve, H. H. 2012. The German Riding Pony: a genealogical study and a genetic analysis. *63rd Annual Meeting of the European Association for Animal Production, Bratislava, Slovakia*. Available at:
http://www.eaap.org/Previous_Annual_Meetings/2012Bratislava/Papers/Published/05_Schoepke.pdf [2015-04-16].

Stewart, I. D., Woolliams, J. A. and Brotherstone, S. 2010. Genetic evaluation of horses for performance in dressage competitions in Great Britain. *Livestock Science*, 128, 36-45.

Thorén Hellsten E. 2008. International Sport Horse Data for Genetic Evaluation. Doctoral Thesis. Swedish University of Agricultural Science. Department of Animal Breeding and Genetics. Uppsala. ISSN 1652-6880. Available at: http://pub.epsilon.slu.se/1754/1/Kappa_080420.pdf [2015-05-12].

Thorén Hellsten, E., Viklund, Å., Koenen, E.P.C., Ricard, A., Bruns, E. and Philipsson, J. 2006. Review of genetic parameters estimated at stallion and young horse performance tests and their correlations with later results in dressage and show-jumping competition. *Livestock Science*, 103, 1-12.

Van Bergen, H.M.J.M. and Van Arendonk, J.A.M., 1993. Genetic parameters for linear type traits in Shetland ponies. *Livestock Production Science*, 36, 273-284.

Viklund Å. 2010. Genetic Evaluation of Swedish Warmblood Horses. Doctoral Thesis. Swedish University of Agricultural Science. Department of Animal Breeding and Genetics. Uppsala. ISSN 1652-6880. Available at: http://pub.epsilon.slu.se/2336/1/viklund_asa_100831.pdf [2015-04-13].

Viklund, Å., Braam, Å., Näsholm, A., Strandberg, E. and Phillips, J. 2010. Genetic variation in competition traits at Different Ages and time period and correlations with traits at Field Tests of 4-year-old Swedish Warmblood horses. *Animal*, 4 (5), 682-691.

Viklund, Å., Thorén Hellsten E., Näsholm, A., Strandberg, E. and Phillips, J. 2008. Genetic parameters for traits Evaluated at field tests of three-and four-year-old Swedish Warmblood horses. *Animal*, 2 (12), 1832-1841.

Viklund, Å., Näsholm A., Strandberg E. and Philipsson J. 2011. Genetic trends for performance of Swedish Warmblood horses. Livestock Science, 144, 113–122.

Wallin, L., Strandberg, E. and Philipsson, J. 2001. Phenotypic relationship between test results of Swedish Warmblood horses as 4-year-olds and longevity. *Livestock Production Science*, 68, 97-105.

Wallin, L., Strandberg, E. and Philipsson, J. 2003. Genetic correlations between field test results of Swedish Warmblood riding horses as 4-year-olds and lifetime performance results in dressage and showjumping. *Livestock Production Science*, 82, 61-71.

Softwares

Madsen, P. and Jensen, J. 2013. A User's Guide to DMU, A Package for Analysing Multivariate Mixed Models. Version 6, release 5.2. University of Aarhus, Departement of Molecular Biology and Genetics, Research Centre Foulum, Denmark. Available at: http://dmu.agrsci.dk/DMU/Doc/Current/dmuv6_guide.5.2.pdf [2015-04-13].

SAS (Statistical Analysis Systems). 2015. SAS 9.4 Product Documentation. SAS Institute Inc., Cary, NC, USA. Available at: http://support.sas.com/documentation/94/ [2015-04-13].

Internet addresses

- **New Forest Pony Association (NPF)**

NPFA. 2013. *History*. Available at:
http://www.newforestpony.net/amenities.html [2015-01-29]

- **New Forest Pony Breeding and Cattle Society (NFPBCS)**

NFPBCS. 2011a. *About the New Forest Pony breed*. Available at:
http://www.newforestpony.com/aboutthebreed.php [2015-01-29]

NFPBCS. 2011b. *History of the New Forest Pony*. Available at:
http://www.newforestpony.com/history.php [2015-01-29]

NFPBCS. 2011c. *Breed Standard of the New Forest Pony*. Available at:
http://www.newforestpony.com/breedstandard.php [2015-01-29]

- **Swedish New Forest pony society (Svenska New Forest Föreningen - SNF)**

SNF. 2010. *Plan and guidelines for New Forest ponies in Sweden* (adopted by SNF 2010-11-25). Available at:
http://www.newforest.se/om-oss/plan-o-riktlinjer [2015-01-29]

SNF. 2011. *Conformation and quality index*. Available at:
http://www.newforest.se/hingstar/statistik-reglemente-hingst-och-modernelinjer-kvalitetsindex/exterior-och-kvalitetsindex_855 [2015-05-18]

SNF. 2015a. *New Forest pony's History*. Available at:
http://www.newforest.se/om-oss/historik [2015-01-29]

SNF. 2015b. *History, New Forest (E) and New Forest (S)*. Available at:
http://www.newforest.se/om-oss/historik/new-forest-e-och-new-forest-s [2015-01-29]

- **Swedish Pony Breeding Federation (Svenska Ponnyavelsförbundet – SPAF)**

Ungponny. 2015a. *Advice & Instructions three-year olds test for ponies 2015* (Råd & anvisningar treårstest för ponnyer 2015). Available at:
http://www.ungponny.se/2015/Regionala%20proppar/RAD_ANVISNINGAR_tretest%202015.pdf [2015-01-29]

Ungponny.2015b. *Advice & Instructions quality test for ponies 2015* (Råd och anvisningar för kvalitetsbedömning av ponnyer 2015). Available at:
http://www.ungponny.se/2015/Regionala%20proppar/RAD_ANVISNINGAR_kvalitetsbed%202015.pdf [2015-01-29]

- **Swedish Equestrian Federation (Svenska Ridsport Förbundet – SRF)**

SRF. 2015a. *Show jumping competition regulations* (Hoppning Tävlingsreglemente). Available at: http://www3.ridsport.se/ImageVaultFiles/id_40822/cf_559/TR_III_Hoppning_2.PDF [2015-02-12]

SRF. 2015b. *Dressage competition regulations* (Dressyr Tävlingsreglemente). Available at: http://www3.ridsport.se/ImageVaultFiles/id_40821/cf_559/TR_II_Dressyr_3.PDF [2015-02-12]

SRF. 2015c. *Contents of dressage program book* (Innehåll i Dressyrprogramboken). Available at: http://www3.ridsport.se/ImageVaultFiles/id_41093/cf_559/Inneh-ll_i_Dressyrprogramboken-_2015.PDF [2015-02-12]

SRF. 2015d. *Eventing competition regulations* (Fälttävlan Tävlingsreglemente). Available at: http://www3.ridsport.se/ImageVaultFiles/id_40827/cf_559/IV_Fa-ltta-vlan_webb_enkelsidor.PDF [2015-02-12]

Appendix 1. Estimated Breeding Values (EBVs) for stallions having at least ten tested or competed offspring in Young Pony Test (YPT), Riding Pony Quality Test (RPQT), show jumping competition, dressage competition and/or eventing competition.

Table 1. *Top ten stallions according to their Estimated Breeding Values (EBVs) for the Young Pony Test (YPT) trait jumping talent*

		Number of tested or competed offspring				
Rank	**Name**	YPT	RPQT	Show jumping	Dressage	Eventing
1	Rodlease Dancing Gold	34	38	33	26	2
2	Priory Dallas	14	18	11	8	8
3	Willoway Goldigger	28	28	18	19	1
4	Miclas Activ	10	10	49	1	2
5	Stackarps Peer-Boy	13	0	0	0	0
6	Sturevallens Gentleman	14	13	49	9	3
7	Jolly Roger	14	9	17	8	0
8	Hoppenhofs Jop	18	14	0	0	0
9	Kantje´s Top Boy	11	8	4	3	0
10	Fredriksbergs Dizney	11	8	16	0	3

Table 2. *Top ten stallions according to their Estimated Breeding Values (EBVs) for the Young Pony Test (YPT) trait gait talent*

		Number of tested or competed offspring				
Rank	**Name**	YPT	RPQT	Show jumping	Dressage	Eventing
1	Rodlease Dancing Gold	34	38	33	26	2
2	Priory Dallas	14	18	11	8	8
3	Willoway Goldigger	28	28	18	19	1
4	Fredriksbergs Dizney	11	8	16	0	3
5	Miclas Activ	10	10	49	1	2
6	Stackarps Peer-Boy	13	0	0	0	0
7	Sturevallens Gentleman	14	13	49	9	3
8	Hoppenhofs Jop	18	14	0	0	0
9	Jolly Roger	14	9	17	8	0
10	Kantje´s Top Boy	11	8	4	3	0

Table 3. *Top ten stallions according to their Estimated Breeding Values (EBVs) for the Riding Pony Quality Test (RPQT) trait jumping talent*

		Number of tested or competed offspring				
Rank	**Name**	YPT	RPQT	Show jumping	Dressage	Eventing
1	Sörbys O´Boy	10	16	14	13	1
2	Silverlea Top Hat	4	17	33	5	3
3	Horsemosens Charlie Brown	0	14	32	13	4
4	Lunnalyckans Tacado	7	12	9	6	0
5	Källstorps Curry	1	14	24	20	10
6	Sörbys Lotus	20	31	25	8	2
7	Rolökke Swallow	1	12	22	23	2
8	Casimirsborgs Avocado	2	20	41	28	8
9	Fredriksbergs Chopin	0	11	23	13	8
10	Hoppenhofs Jop	18	14	0	0	0

Table 4. *Top ten stallions according to their Estimated Breeding Values (EBVs) for the Riding Pony Quality Test (RPQT) trait gait talent*

		Number of tested or competed offspring				
Rank	**Name**	YPT	RPQT	Show jumping	Dressage	Eventing
1	Priory Dallas	14	18	11	8	0
2	Rodlease Dancing Gold	34	38	33	26	2
3	Willoway Goldigger	28	28	18	19	1
4	Horsemosens Charlie Brown	0	14	32	13	4
5	Miclas Activ	10	10	49	1	2
6	Sturevallens Gentleman	14	13	49	9	8
7	Sörbys O´Boy	10	16	14	13	1
8	Casimirsborgs Avocado	2	20	41	28	8
9	Fredriksbergs Chopin	0	11	23	13	8
10	Lunnalyckans Tacado	7	12	9	6	0

Table 5. *Top ten stallions according to their Estimated Breeding Values (EBVs) for the Riding Pony Quality Test (RPQT) trait all round talent*

		Number of tested or competed offspring				
Rank	**Name**	YPT	RPQT	Show jumping	Dressage	Eventing
1	Sörbys O´Boy	10	16	14	13	1
2	Horsemosens Charlie Brown	0	14	32	13	4
3	Willoway Goldigger	28	28	18	19	1
4	Priory Dallas	14	18	11	8	0
5	Källstorps Curry	1	14	24	20	10
6	Lunnalyckans Tacado	7	12	9	6	0
7	Sörbys Lotus	20	31	25	8	2
8	Casimirsborgs Avocado	2	20	41	28	8
9	Fredriksbergs Chopin	0	11	23	13	8
10	Rolökke Swallow	1	12	22	23	2

Table 6. *Top ten stallions according to their Estimated Breeding Values (EBVs) for lifetime points in show jumping competitions*

		Number of tested or competed offspring				
Rank	**Name**	YPT	RPQT	Show jumping	Dressage	Eventing
1	Vernons Peeping Tom	5	7	19	18	9
2	Maraschino	0	0	13	5	1
3	Priory Dallas	14	18	11	8	0
4	Cristalls Jolly Jumper	4	8	14	5	4
5	Robin	0	3	20	6	5
6	LL Möllegårdens Marco Polo	3	1	13	4	3
7	Flight	0	2	20	5	4
8	Zansibar	0	4	41	13	9
9	Horsemosens Charlie Brown	0	14	32	13	4
10	Kastor	0	0	11	4	3

Table 7. *Top ten stallions according to their Estimated Breeding Values (EBVs) for the ratio lifetime points/number of starts in show jumping competitions*

Rank	Name	Number of tested or competed offspring				
		YPT	RPQT	Show jumping	Dressage	Eventing
1	Vernons Peeping Tom	5	7	19	18	9
2	Pantaco	6	3	15	9	3
3	Zansibar	0	4	41	13	9
4	Valentin Bell	0	6	14	13	2
5	Flight	0	2	20	5	4
6	Maraschino	0	0	13	5	1
7	Cristalls Jolly Jumper	4	8	14	5	4
8	Robin	0	3	20	6	5
9	Sörbys O´Boy	10	16	14	13	1
10	Mustang	0	3	12	6	2

Table 8. *Top ten stallions according to their Estimated Breeding Values (EBVs) for lifetime points in dressage competitions*

Rank	Name	Number of tested or competed offspring				
		YPT	RPQT	Show jumping	Dressage	Eventing
1	Zansibar	0	4	41	13	9
2	Vernons Peeping Tom	5	7	19	18	9
3	Valentin Bell	0	6	14	13	2
4	Sörbys O´Boy	10	16	14	13	1
5	Peregrin	0	9	7	10	4
6	Silverlea Rambo	0	7	14	10	3
7	Silverlea Buckskin	0	5	15	13	6
8	Källstorps Curry	1	14	24	20	10
9	Merrie Master	0	0	20	13	5
10	Casimirsborgs Avocado	2	20	41	28	8

Table 9. *Top ten stallions according to their Estimated Breeding Values (EBVs) for the ratio lifetime points/number of starts in dressage competitions*

Rank	Name	Number of tested or competed offspring				
		YPT	RPQT	Show jumping	Dressage	Eventing
1	Vernons Peeping Tom	5	7	19	18	9
2	Valentin Bell	0	6	14	13	2
3	Willoway Goldigger	28	28	18	19	1
4	Sörbys O´Boy	10	16	14	13	1
5	Rodlease Dancing Gold	34	38	33	26	2
6	Peregrin	0	9	7	10	4
7	Rolökke Swallow	1	12	22	23	2
8	Värends Pedro	0	6	32	20	6
9	Zansibar	0	4	41	13	9
10	Källstorps Curry	1	14	24	20	10

Table 10. *Top ten stallions according to their Estimated Breeding Values (EBVs) for lifetime points in eventing competitions*

Rank	Name	Number of tested or competed offspring				
		YPT	RPQT	Show jumping	Dressage	Eventing
1	Smedhults Cavat	0	4	43	14	21
2	Dennie	0	2	41	14	10
3	Källstorps Curry	1	14	24	20	10