Swedish University of Agricultural Sciences
Faculty of Veterinary Medicine and Animal Science

Genetic Analysis of Eventing Data in the Swedish Warmblood Population

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Abstract

Within Sweden the genetic evaluation of eventing has never been done. With the evaluation of eventing for the Swedish Warmblood (SWB) population a more conclusive summation can be developed for individual horses since many compete within more than one discipline. In this study the equestrian discipline eventing was genetically analyzed in the SWB. Descriptive statistics on the population was also analyzed. This was completed by using competition results from 1961 to 2009 and results from Riding Horse Quality Test (RHQT) for 4-year-old horses from 1973 to 2010. Eventing has a small number of competing horses when compared to show jumping and dressage. It was found that an eventing horse competes on average 2.1 years in eventing competitions. The horses seem to start at a later age since the mean age of 8.5, during competition, was found. Then 85% of horses that competed in eventing also competed in other disciplines. Eventing and show jumping was the highest combination of disciplines. There were also more male horses than mares that competed in eventing which corresponded to other studies.

An animal model was used to analyze different traits reflecting eventing performance, and at different ages and to investigate correlations to show jumping and dressage and traits judged at RHQT. The eventing traits points, placing, and points per placing were all found to be heritable (0.06-0.17). There were high genetic correlations between three specific age groups (4 to 6 years of age, 4 to 9 years of age and lifetime) ranging from 0.76 to 0.99. The trait accumulated lifetime eventing points was suggested to use in genetic evaluation due to higher genetic variance and to include as much information as possible. Lifetime accumulated points were also used for show jumping and dressage. Show jumping was found to be moderately correlated to eventing with a genetic correlation of 0.44 whereas dressage was not found to be correlated to eventing. For RHQT traits associated with jumping (jumping technique and temperament for jumping) and canter the correlations to eventing were moderately correlated (0.31-0.41) and the rideability was found to have a correlation of 0.14 to eventing.

From the high correlations between the three specific age groups in eventing it was concluded that using the information of points earned in eventing competitions by younger horses could predict the performance outcome at an older age. The genetic trend for the estimated breeding values was found to be increasing even though there is no selection for eventing horses in Sweden at this time. Due to the moderate correlation between eventing and show jumping, and between eventing and jumping traits in RHQT, selection for better show jumping SWBs would also have a positive effect on the eventing SWBs. Overall, the eventing horses within the SWBs are slowly becoming better without direct selection but if selection was desired the performance of younger eventing horses could be used to predict competition performance later in life.

Introduction

The equestrian sport eventing is considered one of the hardest equestrian sports for horse and rider. An eventing horse needs to be a combination or compromise of three horses: jumping, dressage, and cross country. For a successful career in eventing, a horse needs stamina and agility. The eventing horse must be at top condition to be able to compete in more than one discipline in such a short amount of time (Svenska Ridsportförbundet, 2008).

The overall breeding objective for the Swedish Warmblood is "to produce a noble, correct and durable riding horse which through its temperament, rideability, good movements and/or jumping ability is internationally competitive" (ASVH, 2006). In the detailed description of the breeding goal, it is stated that the eventing horse should be brave, determined, patient, large stride especially at a canter, and be of light type. However, today there are no breeding values available for eventing. Compared to show jumping and dressage, eventing has fewer competitors within Sweden. There have not been many studies published on the eventing sport when compared to sports such as dressage and show jumping.

In France and the United Kingdom, there have been two studies on eventing (Ricard and Chanu, 2001; Kearsely et al., 2008). These studies found eventing had a low heritability and could be improved by breeding. Both studies found that selection of an eventing horse's performance based on novice performance was possible.

Eventing has been present as an equestrian sport in Sweden since 1912. At this point in time, the eventing competition data collected within Sweden has not been used in genetic analyses. A study of eventing data will give a more complete evaluation of the SWB. With more information about the discipline, eventing may become a more prominent sport in Sweden. This may result in the selection of better eventing horses. The study will increase the knowledge of specific horses since many horses compete in multiple disciplines. Horses competing in show jumping and dressage have already been genetically evaluated (Viklund, 2010).

The aim of this study was to analyze the equestrian sport eventing data within the SWB population. First, descriptive statistics will give information of the structure of the eventing horse population. Second, genetic parameters of different eventing traits, and at different ages, will be estimated to investigate if the traits are heritable and how they are correlated. Third, genetic correlations between eventing and results from Riding Horse Quality Test for 4-year-olds, and between results in eventing and dressage and show jumping will be estimated.

Literature Review

The Swedish Warmblood Horse

In history, the Swedish Warmblood (SWB) was used in the military cavalry division and for farm work. The interest in competition grew stronger after Sweden hosted the Olympic Games in 1912 (Graaf, 2004). It led to an increase in demand for competition horses within Sweden and there had to be a change in the breed for more suitable competition horses. The Swedish Warmblood Association (SWA) was founded in 1928 to improve the breed (Viklund, 2010). However, horses were mainly produced for the cavalry until the 1960's. The best horses were used by cavalry officers competing in the Olympics. It was not until the late 1950's that it started to be a market for civil sport horses.

The overall breeding objective for the Swedish Warmblood is "to produce a noble, correct and durable riding horse which through its temperament, rideability, good movements and/or jumping ability is internationally competitive" (ASVH, 2006). Today, the SWA's goal is to have a breed specialized in dressage and show jumping (Viklund, 2010). In the more detailed description of the breeding goal, the eventing horse should be brave, determined, patient, large stride especially at a canter, and be of light type (ASVH, 2006). This is preferably reached by covering mares with good dressage and jumping abilities with Thoroughbred stallions, or by covering Thoroughbred mares with stallions with good dressage and jumping abilities.

The Swedish Warmblood Studbook is an open studbook (ASHV, 2011). The SWB studbook includes many European Warmblood breeds that have something to offer to the improvement to the Swedish Warmblood breed (Viklund, 2010). This allows for more genetic change and helps decrease inbreeding. However, inbreeding today is not a problem within the SWB population. Koenen et al. (2004) found that 62 percent of mares registered in the SWB were bred to a foreign stallion in 2002. Today around 80 percent of the foals are by a foreign-born stallion. This is a large change from the 1980's where 80 percent of the mares were bred to Swedish-born stallions (Thorén Hellsten et al., 2009). These percentages show that the influence of foreign horses is still increasing. This is most likely because of the development of new breeding methods. In the 1980's, more than 90 percent of the SWB broodmares were covered naturally. Today most (>90%) of the SWB broodmares are covered by artificial insemination (AI) (Thorén Hellsten et al., 2009). The breeds that are the most frequently used historically in the studbook are Thoroughbred, Hanoverian, and Trakehner (Viklund, 2010). Today the Dutch Warmblood (KWPN) and Holsteiner are used to a large extent.

As stated, the goal of SWA is to have competitive horses within dressage and show jumping. SWA has implemented different tests to help in the selection of the best animals within the population at an earlier age. This is needed since high levels of competition are reached at an older age. To improve the quality of breeding stallions, Sweden introduced a specific regulation for prospective breeding stallions in 1914. From the late 1970's prospective breeding stallions for SWB are tested at a week-long stallion performance test ages of 3 to 5 years. These stallion performance tests include specific traits like conformation, temperament, soundness, and jumping traits. The idea of the chosen traits is to evaluate the overall quality of the stallion and be the basis of stallion selection.

There are also performance tests for three and four year old horses of both sexes. These tests are where most of the data for genetic evaluation is gathered. The aims are to provide an early opportunity for genetic evaluation, early breeding selection, encourage early handling of horses, and evaluate the overall quality of the horses in regards to: health, temperament, conformation, rideability, gaits, and jumping ability. Each trait is evaluated on a 1 (very poor) to 10 (excellent) scale. (Viklund, 2010)

Competition has developed over time in the Swedish Warmblood population (Viklund, 2010). In the past 40 years, the equestrian sport has increased in interest in Sweden from around 680 competitive riders in 1970 to 25,000 competitive riders today (Viklund, 2010). Computerized recording of competition results was done retrospectively since the 1960's mostly for dressage and show jumping. In the beginning, there was a low number of competing horses. Today more than 35 percent of the horses born have official competition records (Viklund, 2010). Competition data are used for genetic evaluation of the Swedish Warmblood horse.

Eventing

The Fédération Equestre Internationale (FEI) provides the rules for the sport of eventing (Svenska Ridsportförbundet, 2011). Eventing is an equestrian sport that requires many years of training and preparation. In French, the word for eventing "concours complet" means complete contest. It is a good description of the sport that includes three different tests: dressage, show jumping, and cross country (endurance) (Svenska Ridsportförbundet, 2008).

The equestrian sport was added to the 1912 summer Olympics in Stockholm because the military wanted the best horses for their needs: responsive, flexible, and agile. Non-military people did not participate until 1924 and women did not compete until 1964. Today eventing is the only "high risk" event that men and women compete in against each other in the Olympics (Eventing, Unknown).

Cross country is the test with the greatest importance in the overall placing, with dressage and show jumping following in that order (Svenska Ridsportförbundet, 2011). The jumping and dressage sections must always be at the same difficulty level as the cross country. The rider with the lowest overall penalty score is the winner of the class. The cross country has three different levels of penalties: first for errors from overcoming the obstacles, second for time errors (exceeding, too short or long, etc.), third for improper conduct or dangerous riding (Svenska Ridsportförbundet, 2011). The penalty points for the dressage division is determined by total score (percentage) divided by number of judges, then subtracted by 100, and finally multiplied by 1.5 (Svenska Ridsportförbundet, 2011). For show jumping, the penalty points are given based on refusals of the jumps, knocking a rail, or time faults.

There are three different difficulty levels of eventing: easy (novice), intermediate (medium), and advanced. Within the levels of difficulty, there are specific classes to best represent the ability of the horse and rider combination. A rider must compete successfully in the lower classes before entering in a higher class. Within the easy level, there are two classes. The horse must be at least the age of four to compete in class 90 (cm height of obstacles) and the age of five for class 100. Medium consists of one and two star classes. For the one star class, the rider must be a least the age of 14, and the horse, the age of six. The last level is advanced, which includes three star and above classes. (Svenska Ridsportförbundet, 2011)

There are two different types of eventing: Long and Short Eventing. The objective of Short Eventing is to evaluate the rider's skill and to improve jumping ability. All three tests are given on the same day: dressage, show jumping and cross country (in order). Short eventing is for the easy classes and the intermediate or medium classes. Most of the competitions entered are Short Eventing (Svenska Ridsportförbundet, 2011). Long eventing is for the more experienced rider where the horse and rider's abilities are tested in-depth. It is only for the advanced classes. Long eventing is completed over a three day period with one discipline each day (dressage, cross country and show jumping). When competing in the different disciplines, the horse and rider are judged on different items. In dressage, the horse and rider combination should "show that the horse is detached, obedient, calm, positive, attentive and in harmony with his rider." (Svenska Ridsportförbundet, 2011) On the second day, cross country tests the speed, stamina of the horse, courage and jumping ability of the cross country terrain (Svenska Ridsportförbundet, 2011). Show jumping, the third test, judges the horse's willingness, energy and obedience to the rider to keep going after the stresses of the cross country class the day before.

Competition Traits

Competition traits are used for genetic evaluation by many Warmblood horse populations. It is important for the populations if the breeding objective is concentrated on sport horses. The traits for genetic evaluation are chosen based on what the equestrian federation records. In some countries, the percentage of marks of total marks in dressage (Stewart et al., 2010), penalty points in eventing phases and total competition (Kearsley et al., 2008), annual earnings and total earnings in competition (Ricard and Chanu, 2001; Schade, 1996; Hassenstein, 1998), and rank in competition (Janssens et al., 1997; Hassenstein, 1998; Reilly et al., 1998; Ricard and Chanu, 2001) are used for genetic evaluation. In Sweden, annual number of placing and upgrading points is recorded and accumulated overall lifetime of each horse. Upgrading points are given to the placed horses, i.e. the top 25% in a competition, and are determined by performance, level of competition, and the amount of participants in the class (Svenska Ridsportförbundet, 2011; Viklund, 2010).

When recording competition results, accurate identification of the horses is vital. Since 1996 for a horse to compete in Sweden, it is required to be registered in a breeding association to have a competition license. This license number is linked to all competition results acquired by the horse (Viklund, 2010). Horses competing before 1996 have been manually recognized with the information recorded at Swedish Equestrian Federation (SvRF). It could be either by the horses' identification numbers given at registration in SWA since 1980, or by their birth year and parents studbook numbers. Studbook numbers have been given all breeding horses in SWB since 1920's.

Genetic Evaluation of the Swedish Warmblood

To achieve a proposed breeding objective, it is imperative to have a successful and accurate breeding program and to understand the specific population. To have a high accuracy of the breeding values, all possible sources of information needs to be included. These sources of information include several generations of pedigree information and performance information of different kinds. The BLUP (Best Linear Unbiased Prediction) animal model is used for genetic evaluation in many different horse populations such as, Sweden, The Netherlands, Denmark, Germany, Ireland, France, and Belgium. The animal model evaluation is not sex limited and can tolerate all ages of stallions and mares used in breeding concurrently and horses from different generations. Within the genetic evaluation, various environmental factors are adjusted. Some environmental factors are birth year, sex, age, year of gathered information, and the location of the event (Viklund, 2010).

For Sweden, the breeding values with a BLUP animal model have been estimated for the Swedish Warmblood (SWB) since 1986 (Árnason, 1987). At that time only data from Riding Horse Quality Test (RHQT) were included. In 2006 data from Young Horse Test (YHT) for 3-year-olds and competition data were included to provide a more accurate evaluation (Viklund, 2010). For the evaluation to be useful, it includes traits that are associated to the SBW breeding objective (Viklund, 2010).

Factors influencing eventing performance

Gender of horse

The influence of a horse's gender on performance has been found in many different horse disciplines. Some of those disciplines are racehorses, trotters, show jumping, and dressage (Gaffney and Cunningham, 1988; Harkins et al., 1992). Normally, it is found that the males tend to have better competition results, especially in dressage, than the females possibly because of body composition (Whitaker et al., 2008). Gender is also relative to behavior and controllability of a horse. For example, a mare going through her heat cycle may be more difficult to handle at competition (Viklund, 2010).

For eventing, there has been an inconsistency with other disciplines findings with respect to the influence of gender. Whitaker et al. (2008) found that there are no significant differences when using penalty scores, final ranks, or lifetime points. Whitaker et al. (2004) and Kearsley et al. (2008) also found no evidence to support an influence of gender on eventing when using penalty scores. When comparing stallions to geldings, stallions did have lower penalties but the difference was not significant. Stallions are the best males and should be the best in competition. Environmental factors such as rider and horse's performance may also have influenced the results.

Month of birth

Depending on the time of birth, a horse is affected by climate, quality of forage, and level and type of parasites. Month of birth was shown to have an effect on the performance of eventing (Langlois and Blouin, 1998). A birth in April was the most advantageous for an eventing horse's performance. Overall, eventing horses had a higher annual earning when the horse was born in the earlier months of the year.

Age of horse

The horse's age has an effect on eventing performance. More young horses compete at low levels of eventing. This is expected since horses must start competing at the lower level (Whitaker et al., 2004).

Ricard and Chanu (2001) and Kearsley et al. (2008) found that younger horses did better in competition at lower levels when compared to older horses at lower levels. In eventing, a horse must compete at the lowest level and move up the divisions based on performance. Usually older horses competing in lower levels of eventing were the worst performers since they did not have the skill to excel (Whitaker et al., 2004). Also, with the older horse, more physical problems occurred that influenced the horses' total performance. Across all levels of eventing, older horses compete at higher levels.

In other disciplines, it is found that the horse's skill increases with age (Kearsley et al., 2008; Viklund, 2010; Stewart et al., 2010). This is also true in eventing until the horse reaches middle age.

Age was found to affect eventing performance when interacting with month of birth (Langlois and Blouin, 1998). One reason for this was the effect of real age in the same age class. This could decrease with increased age. The second reason thought for this interaction was a seasonal effect. It was thought that the seasonal effect would be stable during the horse's life or would increase with age because of the increase of competition difficulty.

Rider

The riders have an influence on the outcome of competition. Kearsley et al. (2008) found that the rider has the biggest influence on the dressage portion of eventing. The show jumping and cross country portion is less affected. This is possibly due to the difference in the event types. Training for jumping and flat disciplines is different as well as how they are shown. Dressage requires more contact with the horse. Riders have more influence within the advanced levels of competition. This is understandable from the increased difficulty (Kearsley et al., 2008). The riders should have more experience as well as better horses at higher levels of competition.

Gender of rider

Male riders were found to have better overall scores (less penalty points) than female riders (Whitaker et al., 2004). There are few male riders in show jumping, dressage, and eventing. Most male riders are considered professionals. Their motivation may be for financial gain or an increase in clients. Males are, also, physically stronger when compared to the average female. They are able to handle more difficult horses and have more stamina at competition.

Place of competition

Different event locations do affect eventing performance. Whitaker et al. (2004) found a large difference between six different eventing facilities. The terrain and the difficulty of the courses were different at all facilities regardless of the level of eventing. The author concluded that further research, including more eventing facilities, is needed to have a more precise measure of how much location affects eventing. Furthermore, the dressage score is subjective.

Genetic parameters for eventing

Heritabilities

Heritabilities were found for overall competition per level as well as each individual phase of eventing to be greater than zero (Ricard and Chanu, 2001; Kearsley et al., 2008). Ricard and Chanu (2001) used earning and rank whereas, Kearsley et al. (2008) used penalty points to estimate heritabilities. Ricard and Chanu (2001) and Kearsley et al. (2008) found heritability for overall eventing competition of 0.05 to 0.07. Both studies had lower overall competition heritabilities for eventing than heritabilities found in dressage or show jumping in studies by Aldridge et al. (2000), Reilly et al. (1998), Viklund (2010), and Wallin et al. (2003).

The two studies on eventing by Ricard and Chanu (2001) and Kearsley et al. (2008) estimated heritabilities for the different phases and disciplines of eventing. Ricard and Chanu (2001) found higher heritabilities for the different disciplines, steeplechase (0.14), show jumping (0.24) and dressage (0.19) than for the overall results. Kearsley et al. (2008) found the highest heritabilities for cross country phases (0.03) in pre-novice, show jumping (0.23) in advanced and dressage (0.11) in intermediate. When the heritabilities were estimated for the different levels of eventing Ricard and Chanu (2001) found a lower heritability for low level eventing compared to Kearsley et al. (2008) but found similar results for the higher levels of eventing.

Genetic correlations between results at different ages

According to the genetic correlation between ages, Ricard and Chanu (2001) found that the performance of horses in the ages 5 to 6 years could be used for genetic evaluation if all the traits were analyzed in the same way overtime. Horses that had a high amount of earnings in the first years of competition also had high levels of earnings later in life. Ricard and Chanu (2001) estimated genetic correlations between results at the ages of 5, 6 and 7 years to 0.75 - 0.94. Then between the ages of 7 and 8 years the genetic correlations were between 0.90 – 0.98. The lowest genetic correlation was between 5 and 7 years of age but sill moderately correlated. From Richard and Chanu (2001) findings it was shown that horses can be chosen at an earlier stage in life to predict later performance. The use of age to predict later performance is also found in other disciplines (Viklund, 2010; Huizinga and van der Meij, 1989).

Genetic correlation between disciplines

The genetic correlations between eventing and other disciplines have been found to be low to moderate. Ricard and Chanu (2001) found that steeplechase had the lowest correlation of 0.18 with eventing and dressage had the highest correlation of 0.58. Show jumping had a correlation of 0.45. For eventing to be moderately correlated with largely dressage and show jumping there could be a possibility to improve the eventing horses without having to sacrifice selection of other disciplines. This would cause any type of selection done on these three disciplines to have a positive effect on eventing within the French population.

Genetic correlations between phases

Kearsley et al. (2008) found that there were low to high correlations between the three phases of eventing, dressage, show jumping, and cross country. The dressage phase of eventing was found to have the highest correlation to overall competition (0.8). The lowest correlation was between dressage and show jumping phases (0.13). Results of the cross country phase were found to be more correlated to the results of the jumping phase than the dressage phase. Within the phases of eventing, both show jumping and dressage are correlated to the overall competition. The level the competition affects the correlations. Therefore both level and phase must be accounted for to have an accurate picture of the phase's correlations.

Genetic correlations between levels

When making a genetic analysis using ranks, earnings, or penalty points, one important thing is to determine if a horse winning at a low level is the same as winning at a higher level of competition. This can be difficult when using annual earning information since horses can compete at different levels throughout the year (Kearsley et al., 2008).

The genetic correlation between levels was close to one (0.99) for eventing (Ricard and Chanu, 2001; Kearsley et al., 2008). This showed that the levels of eventing were connected and that the traits were continuous throughout the levels. In the study by Kearsley et al. (2008) there was more distinction between the pre-novice level of eventing and the higher levels. Based on this, horses could be selected for eventing based on low level performance in eventing (Ricard and Chanu, 2001; Kearsley et al., 2008).

This Study

Material

Pedigree Data

The pedigree information used in this study was given by the Swedish Warmblood Association (SWA). The data contained a total of 236,752 horses. The horses' birth years ranged from 1874 to 2010 but there were 30 percent (70,343) of horses with unknown birth years. The information in the data were; Internal ID Number, Name, Sex (male, female), Birth Year, ID Number (Swedish), Foreign Number and studbook number for the individual horse, Internal ID Number, Name, Birth Year and Studbook Number for sire, dam and maternal grandsire. The internal ID number is a database number.

Competition Data

The competition data were received from the SvRF. Both annual competition results and lifetime records were used. The lifetime records were calculated from the annual competition information from 1961 to 2009. In total there were 53,625 horses with competition data. There were 58.9 (31,586) percent males and 41.1 (22,038) percent females in total with one horse with an unknown sex. Within the competition data, there were 75.2 (40,332) percent horses with show jumping results, 37.7 (20,249) percent horses with dressage results, and 8.14 (4,366) percent horses with eventing results. Thus, 21% of the horses competed in more than one discipline.

Missing IDs in eventing

There were 1486 (34%) of the eventing horses with unknown ID. Moreover, 874 (20%) horses were missing ID of the sire, 769 (17.6%) horses were missing the ID for the dam and 1292 (29.6%) horses were missing the ID of the maternal grandsire. With data editing a total of 438 unknown horses IDs were found; 127 individuals, 132 sires, 96 dams, and 83 maternal grandsires. Within the found individuals one specific horse could have been found multiple times if the horse was bred various times and all offspring were missing that information. If there was no internal ID given or found for the horse, an "imaginary" number was given to horses when the internal IDs of at least one of the following were known: father internal ID, mother internal ID, or maternal grandfather ID. Within the pedigree data, 6.5 (15,193) percent of horses have an assigned imaginary number. In the competition data set, 20 (12,719) percent of the horses have assigned imaginary numbers. All of the found information as well as the assigned numbers were then added to the known information and used in the genetic analysis.

Eventing data

The eventing information included number of starts within eventing, number of placings in easy, medium, and advanced classes, wins in advanced (1^{st} place), lifetime accumulated points in eventing, lifetime accumulated placings in eventing, points per placing in eventing (ratio), and amount of years in eventing. The point per placing ratio trait shows the level of success without considering endurance. The traits lifetime accumulated points, lifetime accumulated placings, and points per placing were all transformed with 10-log to a nearly normal distribution. To calculate the log for horses with a zero for any of the three transformed traits the number 1 had to be added before transformation. The eventing horses were divided into age groups of 4 to 6 years, 4 to 9 years, and lifetime based on age at competition. The horses were born from 1956 to 2004. The competition years were between 1964 and 2009. There were 64.7 (2,824) percent males and 35.3 (1,542) percent females in the total eventing data. The total number of sires was

1,244 (755 known ID, 489 known name). In total there were 4366 horses however, 568 horses had missing information (birth year or internal ID number) and could not be used in the analysis. The number of horses, mean, standard deviation, maximum and minimum for transformed lifetime competition traits of eventing are shown in table 1.

Table 1. Description of data used for estimation of log transformed eventing points, placings, and points per placing used in the genetic analysis

Eventing trait	Number of horses	Mean	s.d.	Minimum	Maximum
Points	3798	0.54	0.64	0	3.06
Placings	3798	0.37	0.39	0	1.76
Points per placing	3798	0.33	0.36	0	1.57

Show jumping and dressage competition data

The numbers of horses (total and number of horses with result in eventing), mean, standard deviation, maximum and minimum for transformed competition traits for dressage and show jumping are shown in table 2.

Table 2. Description of dressage and show jumping data included in the genetic analyses. Number of horses, mean, standard deviation (s.d.), minimum, and maximum of log transformed accumulated points

Competition trait	Number of horses (number of horses with eventing result)	Mean	s.d.	Minimum	Maximum
Dressage lifetime accumulated points	18282 (1520)	0.96	0.83	0	4.25
Show Jumping lifetime accumulated points	34070 (3113)	1.11	0.81	0	4.15

Riding Horse Quality Test (RHQT)

The traits used from the RHQT were canter, jumping technique, jumping temperament, rideability, wither height, walk, trot, and type. The numbers of horses (total and number of horses with result in eventing), mean, and standard deviation (s.d.), for the RHQT are shown in table 3.

Table 3. Description of Riding Horse Quality Test (RHQT) data included in the genetic analyses. Number of horses, mean, standard deviation (s.d.) for each RHQT trait

Trait[1]	Number of horses (number of horses with eventing result)	Mean	s.d.
Jumping Technique	19779 (843)	6.67	1.41
Jumping Temperament	19779 (843)	6.80	1.56
Rideability	19779 (843)	6.63	0.99
Type	19752 (843)	7.73	0.55
Wither Height	15299 (668)	164.60	4.38
Walk	19740 (843)	6.65	1.02
Trot	19740 (843)	6.33	1.02
Canter	19740 (843)	6.68	1.00

[1]RHQT traits are scored from 1(worst) to 10(best)

The correlations between eventing and traits from Young Horse Test (YHT) for 3-year-olds were also completed in this study. The YHT was introduced in 1999 and there were very few horses that had result in both YHT and eventing. The estimated parameters had too high standard errors to give an accurate conclusion and are therefore not reported. The traits tested were canter, jumping technique, and jumping temperament. It will be beneficial to redo the bivariate analysis when more information is available in the future.

Methods

The eventing information was managed, edited and arranged using SAS (SAS, 2008). Basic statistics such as frequencies of sex, birth years, competition information, sire and offspring information was done in SAS. The fixed effects for the final statistical model were found by an analysis of variance using the GLM procedure in SAS. Sex and birth year effects were tested in the model. Birth year was tested because horses with the same birth year had the same amount of likelihood to succeed in eventing competition. The traits tested in the model were the log-transformed data for accumulated points, placings, and the ratio between points and placings.

The analysis of variance showed that effects of sex and birth year were highly significant ($p<0.001$) for all eventing traits. The R^2 (coefficients of determination) values for the eventing data showed that 0.64% to 28.79% of the variation were ascribed to the model using both sex and birth year with birth year having the most influence on the eventing traits.

Statistical models for genetic analysis

According to the results from the analysis of variance, the animal model used for evaluating eventing competition traits was:

$$y_{ijk} = Sex_i + Birth\,Year_j + Animal_k + e_{ijk}$$

where y_{ijk} is the transformed score with 10 – log of each trait for *k*th horse; Sex_i is the fixed effect of the *i*th (*i* = male or female); $Birth\,Year_j$ is the fixed effect of the *j*th birth year (*j* = 1953 – 2004); $Animal_k$ is the random effect of the *k*th horse ~ ND(0, Aσ_a^2), and e_{ijk} is the random ~ IND(0, σ_e^2) residual effect. The same model was used for lifetime accumulated points in dressage and show jumping according to earlier study by Viklund et al. (2010).

Models that were also used in the analysis were for the Riding Horse Quality Test (RHQT) developed by Viklund et al. (2008). For RHQT traits the model was:

$$y_{ijkl} = Sex_i + Age_j + Event_k + Animal_l + e_{ijkl}$$

where y_{ijkl} is the score of each trait for *k*th horse; Sex_i is the fixed effect of the *i*th sex (*i* = mare, gelding/stallion); Age_j is the fixed effect of the *j*th age (*j* = 4 or 5 years of age); $Event_k$ is the fixed effect of the *k*th combination of year and place of the test (*k* = 1,…, 305); $Animal_l$ is the random effect of the *k*th horse ~ ND(0, Aσ_a^2), and e_{ijkl} is the random ~ IND(0, σ_e^2) residual effect.

Genetic Parameter Estimation

The traits were genetically evaluated using the DMU package for analyzing multivariate mixed models (Jensen and Madsen, 1997). Heritability and correlations were given for each analysis. Each trait was evaluated in a chosen model type:

A bivariate model was applied for lifetime eventing points with lifetime points in show jumping or dressage and for lifetime eventing points with RHQT traits; canter (free or under rider), jumping technique and ability (free or under rider), jumping temperament (free or under rider), and temperament for gaits, respectively.

For the trivariate model, ages grouped were for competing eventing horses: 4 – 6 years of age, 4 – 9 years of age and total lifetime of competition. Analysis was done for the three groups for eventing points, placings and the ratio points per placing.

Results

Population Statistics

Figure 1 shows the birth year distribution of the eventing horses. There was an increase in competing eventing horses over the birth year 1991 being the largest. Beginning in 1992, there was a large decrease in competing horses. The birth years of the eventing horses follows the same trend as total horses born but a large majority of total born competing horses do not become eventing horses. There were a low number of eventing horses that were competing in eventing by birth year.

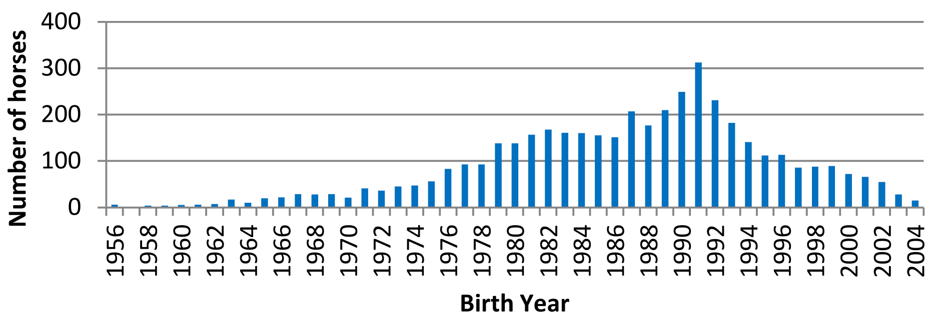

Figure 1. Number of horses by birth year for eventing horses.

The majority of sires (353 of 755 sires with known ID) had produced only one eventing offspring, and 84 sires had two offspring in eventing. The highest amount of offspring in eventing was 54 (one sire).

Table 4 shows the top five sires for number of offspring competing in eventing with their total offspring as well as their number of competing offspring. The fifth top sire was National Zenith xx with 244 offspring, 84 competing, which gave the highest percentage of offspring competing in eventing within the sires of eventing horses. The top four sires in the number of offspring competing in eventing were also in the top six sires with regard to number of competing offspring. Many of these sires' offspring could be used for any sport, not just for eventing. Only National Zenith xx with 84 competing offspring was perhaps bred more for eventing competition than the other four stallions.

Table 4. Top five sires with highest number of eventing offspring shown with their total offspring, number of competing offspring and percent eventing horses out of total offspring

Name and studbook number	Total number of offspring	Competing offspring	Number of offspring in eventing	Percent eventing offspring out of total offspring
Robin Z 423	1403	763	54	4
Maraton 600	1449	533	53	4
Ceylon 454	962	425	50	5
Utrillo 432	960	547	40	4
National Zenith xx 802	244	84	35	14

Figure 2 shows the number of competing horses available in the data that participated in a discipline from 1961 to 2009. If a horse competes in multiple disciplines in the same year, it is included in each category for that year. Overall, jumping had the most competing horses, followed by dressage, then eventing. There was a large increase in competition horses that competed in 1983. This was due to a change in recording routines where all shown horses were recorded (Gelinder, 1999).

In the eventing discipline, there were no competition results reported from 1983 and 1984. There was a large decrease in the jumping and dressage disciplines when compared to eventing from 1989 to 1992. This was due to a change in the method of recording when again only placed horses were recorded (Gelinder, 1999). Jumping had the largest decrease in registered competition horses; dressage was second, but eventing was not affected. Then in 2006 there was an increase in the number of horses for jumping and dressage whereas eventing only increased slightly. Again, the recording had changed to include all started horses (Viklund, 2010).

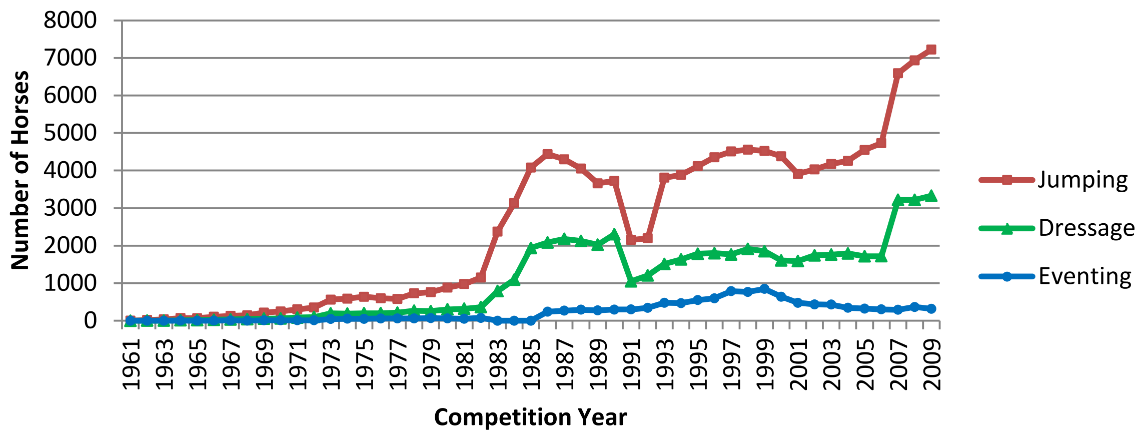

Figure 2. Number of competition horses available in the data and that competed in respective discipline from 1961 to 2009.

Many horses (85%) with eventing results competed in more than one discipline (Table 5). The highest percentage was for horses competing in eventing and show jumping (47%). Horses competing in eventing, jumping, and dressage (32.7%) were second. The lowest percentage was for horses competing in eventing and dressage (5%).

Table 5. Number and percent of horses competing in specific disciplines

Discipline	Number of horses	Percentage of the eventing horses
Eventing Only	653	15.0
Eventing and Jumping	2066	47.3
Eventing and Dressage	218	5.0
Eventing, Jumping, and Dressage	1429	32.7

Around 40% (1,820) of horses with eventing results competed for one year (Figure 3). The percentage could have been higher since horses can compete but not been placed and therefore no results were found for that horse. The percentage dropped to 20% (956 horses) for two years of competing. After eight years of competition, only 1.4% (64 horses) competed. The percent of horses that competed above eight years was approximately 0.5%. The highest number of eventing years for a horse was 16 with a percentage of 0.02 (1 horse).

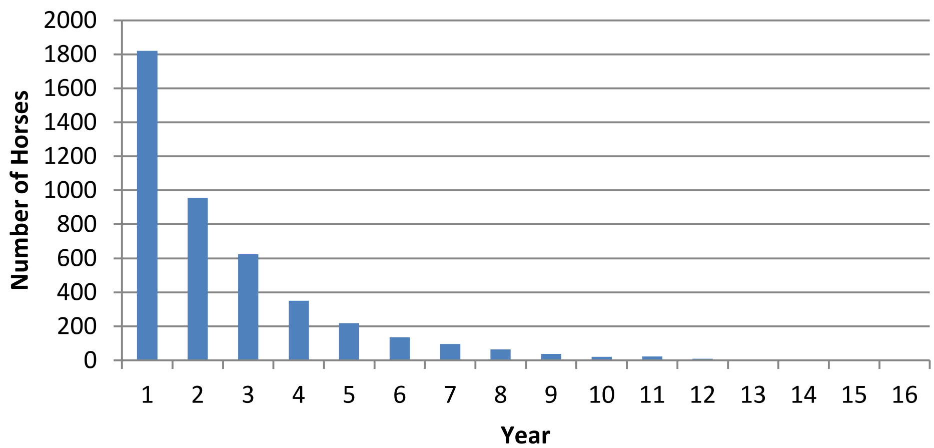

Figure 3. Number of years a horse competed in eventing competition.

The average of years in competition was approximately 2.19 years for horses born from 1970 to 1977 in eventing. For horses born between 1978 and 1997 the average increased to around 2.5 years. There was a decrease to approximately 2 years for horses born between 1998 and 2001. For horses born after 2001, the more recently born horses mean years in competition was approximately one. However, this may be the result that their careers in eventing have just started and may be higher than actually shown currently.

Figure 4 shows the number of horses and their age at eventing competition. An eventing horse competes mostly around the age of seven to nine. The mean age of the eventing horse is 8.36 years old. The largest number of horses competing in eventing was at the age of eight with 1,526 horses. There were only four horses that competed at four years of age. A horse cannot compete in eventing until they are at least the age of four. This increases to 723 horses that competed at the age of five. There were horses that competed older than five, possibly being the more competitive horses. There were more than 100 eventing horses competing until the age of 18 (56 horses). (Not included in this figure are horses at the age of 22 to 24 (3, 2, 2 horses) and 31 (1 horse))

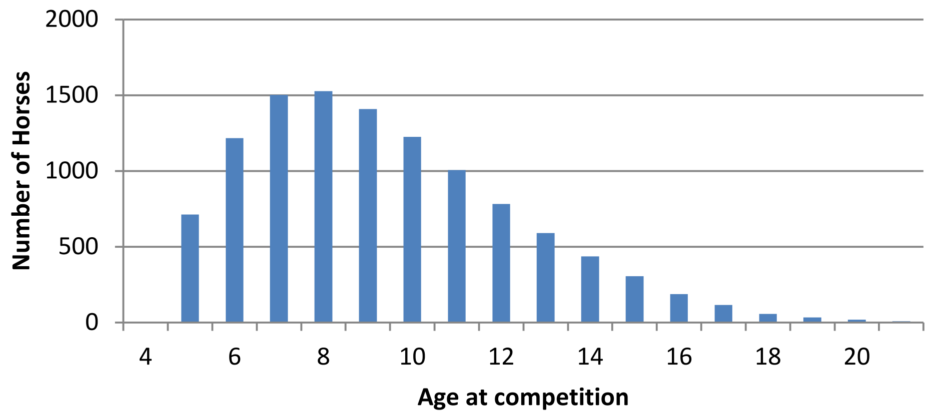

Figure 4. Number of horses in different ages at eventing competition.

Table 6 shows the number of horses that have placings and winnings in the easy, medium, and advanced levels of eventing and includes the highest lifetime achievement level for horses. Because all horses must start in the lower, easy class, it is expected that there would be more horses with competition results at this level than at the other levels. Horses that do not excel at eventing tend to quit at this level. According to this table, this was not true. It shows that more horses have competition results in the medium level (1,539) than in the easy (1,471), and advanced (294) levels. Since the horse must compete in a lower level first there is missing information. This could be from horses entering local shows where only low levels of eventing are shown that are not reported to the SvRF. The results of the horse show up as only entering higher levels but do have the necessary requirements from the lower levels.

There were 883 horses that competed at the easy level. 1301 horses competed until the medium level, but there were only 294 horses that competed through the advanced level. Only the best horses accomplish the advanced level. In the eventing population, there is a small number of horses that attain this level.

Table 6. Number of horses in specific levels in eventing and highest level achieved by an individual horse in each level

Level of Eventing	Number of Horses
Placed or won in easy	1471
Easy (highest achievement)	883
Placed or won in medium	1539
Medium (highest achievement)	1301
Placed or won in advanced	294
Advanced (highest achievement)	294

Table 7 shows the number of horses that won or were placed at the highest level in dressage or show jumping when compared to the highest achieved level in eventing. There were more horses that competed in show jumping and also in eventing at all levels than in dressage and eventing. Of the 833 horses that competed up to the easy level, 34% (284) also competed up to the easy level in show jumping. In dressage, only 5% (46) compete in both easy divisions. In show jumping, there were eight horses that competed up to medium while also competing in advanced level eventing.

Table 7. Number of horses that won or placed to the highest level in dressage or show jumping when compared to highest level in eventing

	Discipline						
	Eventing	**Dressage**			**Show Jumping**		
Eventing		**easy**	**medium**	**advanced**	**easy**	**medium**	**advanced**
Easy	833	46	6	1	284	69	5
medium	1301	15	4	0	205	82	11
advanced	294	1	0	0	15	8	0

Genetic Analyses

Eventing

Table 8 shows the heritability and additive genetic variance for eventing competition traits in different age groups. The heritabilities for eventing for the different age groups were low from 0.06 to 0.17. The highest heritabilities were found for the age group 4 to 6 years of age for all three eventing competition traits. The competition traits lifetime accumulated points and lifetime accumulated placings show higher heritabilities than the lifetime accumulated points per placing. The additive genetic variances for lifetime accumulated points and lifetime accumulated placings doubled for the lifetime age group, whereas the lifetime accumulated points per placing competition traits decreased .002 for the lifetime age group. The genetic variance was higher for lifetime points and was therefore used for the rest of the genetic analyses.

Table 8. Heritabilities (h^2) and additive genetic variances (σ_a^2) with standard errors as subscript for eventing competition traits in different age groups

Age groups	h^2			σ_a^2		
	Points	**Placings**	**Points/placing**	**Points**	**Placings**	**Points/placing**
4 to 6 years	$0.14_{.05}$	$0.17_{.05}$	$0.11_{.04}$	$0.02_{.008}$	$0.01_{.003}$	$0.007_{.003}$
4 to 9 years	$0.11_{.03}$	$0.16_{.04}$	$0.06_{.03}$	$0.02_{.008}$	$0.01_{.003}$	$0.005_{.002}$
Lifetime	$0.12_{.03}$	$0.16_{.04}$	$0.06_{.03}$	$0.04_{.01}$	$0.02_{.005}$	$0.005_{.002}$

Table 9 shows the genetic and phenotypic correlations between eventing competition traits in the different age groups. Between all age groups the genetic correlations were high, 0.76 to 0.99. The phenotypic correlations were moderate to high, 0.62 to 0.90. The highest correlation was between the 4 to 9 years and lifetime groups. The lowest correlation was between 4 to 6 years and lifetime groups. This was also true for the phenotypic correlations.

Table 9. Genetic (r_g) and phenotypic correlations (r_p) between eventing competition traits in different age groups

Age groups	r_g [a]	r_p
4 to 6 years - 4 to 9 years	0.84 to 0.91	0.74 to 0.76
4 to 6 years - lifetime	0.76 to 0.83	0.62 to 0.68
4 to 9 years - lifetime	0.96 to 0.99	0.87 to 0.90

[a] Standard errors for genetic correlations were between 0.01 and 0.17

Table 10 shows the genetic correlations with standard error and phenotypic correlations from bivariate analysis of accumulated lifetime eventing traits. As assumed there were high correlations between the different lifetime eventing traits. Lifetime points and lifetime points per placing was almost one with 0.99. The lifetime points and placings as well as lifetime placings and points per placing were both 0.97. All genetic correlations were higher than the phenotypic correlations.

Table 10. Genetic correlations with standard error as subscript and phenotypic correlations from bivariate analysis of accumulated lifetime eventing traits

Trait	r_g	r_p
Points – Placings	$0.97_{.02}$	0.89
Points - Points per placing	$0.99_{.05}$	0.90
Placings - Points per placing	$0.97_{.05}$	0.72

Bivariate Analysis with lifetime points for dressage, jumping, and RHQT traits

Table 11 shows the heritabilities and additive genetic and residual variances with their standard errors for competition traits – lifetime dressage points and lifetime show jumping points; and RHQT traits – canter, jumping technique, jumping temperament, rideability, wither height, type, walk, and trot from the bivariate analyses with lifetime eventing points. Show jumping had the highest heritability of the competition traits with 0.33. Dressage had a moderate heritability of 0.26. For the RHQT, the highest heritability was found for wither height with 0.78 and type second with 0.43. The additive genetic variances found for dressage and show jumping were both approximately 0.20.

Table 11. Heritabilities (h^2), additive genetic (σ_a^2) and residual (σ_e^2) variances with standard error as subscript from the bivariate analysis of eventing points for dressage, show jumping, and Riding Horse Quality Test (RHQT) traits

Trait	h^2	σ_a^2	σ_e^2
Competition			
Lifetime Dressage Points	$0.26_{.02}$	$0.16_{.01}$	$0.47_{.01}$
Lifetime Show Jumping Points	$0.33_{.01}$	$0.20_{.01}$	$0.40_{.01}$
RHQT			
Canter	$0.35_{.02}$	$0.32_{.02}$	$0.60_{.02}$
Jumping Technique	$0.23_{.01}$	$0.42_{.04}$	$1.41_{.03}$
Jumping Temperament	$0.18_{.01}$	$0.41_{.04}$	$1.85_{.03}$
Rideability	$0.32_{.02}$	$0.27_{.02}$	$0.57_{.01}$
Wither Height	$0.78_{.02}$	$15.60_{.70}$	$4.40_{.44}$
Type	$0.43_{.02}$	$0.09_{.006}$	$0.19_{.005}$
Walk	$0.31_{.02}$	$0.29_{.02}$	$0.66_{.01}$
Trot	$0.40_{.02}$	$0.38_{.02}$	$0.57_{.01}$

Table 12 shows genetic correlations with standard error and phenotypic correlations between lifetime eventing points and lifetime dressage points, lifetime show jumping points, and RHQT traits. The correlation between lifetime eventing points and lifetime dressage points was found to be zero (-0.01), whereas there was a high genetic correlation between lifetime show jumping and eventing points of 0.44. Between lifetime eventing points and the RHQT traits most genetic correlations were positive and moderate ranging from 0.14 to 0.41, the highest being with jumping temperament. However, correlations with wither height and trot were slightly negative. Overall the phenotypic correlations were lower than the genetic correlations.

Table 12. Genetic with standard error as subscript and phenotypic correlation between eventing points and lifetime dressage points, lifetime show jumping points, and Riding Horse Quality Test (RHQT)

Traits	r_g	r_p
Competition		
Lifetime Dressage Points	$-0.01_{.14}$	0.08
Lifetime Show Jumping Points	$0.44_{.10}$	0.20
RHQT		
Canter	$0.31_{.13}$	0.05
Jumping Technique	$0.34_{.12}$	0.06
Jumping Temperament	$0.41_{.13}$	0.03
Rideability	$0.14_{.13}$	0.08
Wither Height	$-0.15_{.13}$	-0.007
Type	$0.18_{.13}$	0.05
Walk	$0.26_{.13}$	0.07
Trot	$-0.06_{.13}$	0.05

Genetic trend for eventing points

Figure 5 shows the average estimated breeding values (EBV) for horses that have official results in eventing by birth year, from birth year 1976 to 2004. Overall, the trend in EBV is low but there has been an increase in the EBV for eventing points since 1983. The trend of EBV for the eventing population using eventing points are increasing but in small increments in the last fifteen years of known information. Not included in this figure are birth years from 1956 to 1975 because of low number of horses to give an accurate result. The horses that are not yet ten years old (after 1999) may not have accurate breeding values to be considered in the trend. Many eventing horses have been shown to not compete until 7 to 9 years of age and therefore would possibly not have enough lifetime results to be accurate. It was chosen to leave in the graph because it anyway shows a positive trend.

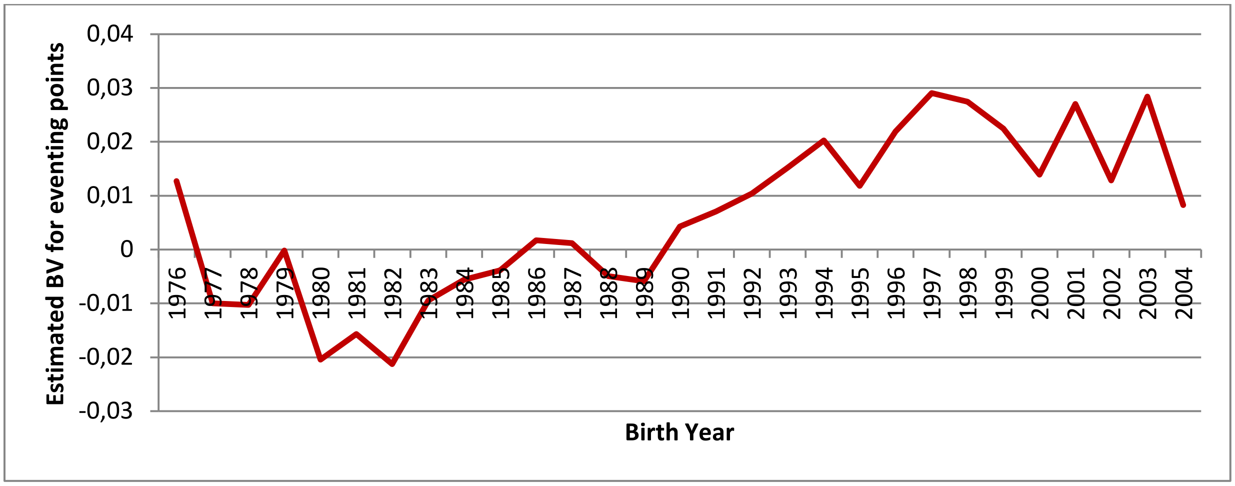

Figure 5. Average estimated breeding value for eventing for birth years 1976 to 2004.

Discussion

Identification of sport horses

There is a small number of competing eventing horses within Sweden today. Therefore it is important to have the most accurate and all the information for a complete evaluation. Today the Swedish Warmblood Association and the Swedish Equestrian Federation work together to link the competition license number with the individual identification number of the same horse. However, imported horses are still a problem to identify. Imported horses can have a competition number linked to the foreign studbook number and then register later in the Swedish Warmblood Association. This causes two different numbers assigned to the same horse causing a loss or repeat of information (Viklund, 2010; Thorén Hellsten et al., 2008). It is also possible that the horse is never linked to the SWA because a horse's license is assigned for a lifetime and maybe only the foreign number was available at that time. Within the study there were horses that did not have an identification number at all and could not be used in the genetic analysis if no 'imaginary' number could be assigned using relative information. The missing identification numbers could have been from lack of information when a horse was imported, being a purebred Thoroughbred, lost ID papers over the years, recorded incorrectly, not recorded and then shown, and/or just misplaced. If these horses could have been included it could have reduced the standard errors found for some parameters in traits tested. The best way to solve this problem is to have only one identification number that is accepted across countries. One possible solution that has been put into use in some European countries is a number called Universal Equine Life Number (UELN). Most major breeding and competition organizations (EU, 2008) have accepted this suggestion. The UELN is still in the beginning stages but if used instead of country specific number this would possibly decrease the amount of errors and decrease the unknown identification numbers for competition horses.

Within the eventing SWB population there are many changes in amount of registered horses in competition over time. One possible reason for the large increase in 1970's may be because more horses were born in those years. The decrease in 2004 could be because these horses are still young and have just started competing in eventing. The result is a lack of information causing what falsely looks to be like a decrease in eventing horses.

Measurement of eventing performance

The best way to genetically analyze eventing is still debatable. The French based their study on competition placings and annual earnings (Richard and Chanu, 2001). The British based their study on using each phase of eventing for genetic evaluation (Kearsley et al., 2008). In this study lifetime accumulated points, placings, and points per placing ratio were used. The French finding based on annual earning is not necessarily the best way to evaluate eventing horses. Not all levels of eventing competition include a purse. This could possibly cause elimination of horses that could be used in the data. Even using ranking for genetic analysis is inadequate since only the top horses are reported/placed till 2007. However, the newer information will include all ranked horses. What is possibly a solution is to have all horses shown placed and recorded. Though, the horses at the bottom would be less accurate since there would be fewer differences in the overall results in the horses placed in the lower ranks. All eventing levels do place so there is less of a loss of possible horses for analysis. Another possible way may be to use each phase of eventing for genetic evaluation as in the British study with all placed horses. This would give more in depth data for analysis, more accurate heritabilities and EBV's for each phase, as well as possibly reduce the high standard errors (for correlations) that were found in this study.

Genetic parameters of eventing

Heritabilities

In this study the heritabilities decreased with higher age groups. Lower heritabilities are normally found with the increase of age because of the large influence of environmental factors (Viklund, 2010). However, in the study by Ricard and Chanu (2001), the authors found higher heritabilities the older the horse. The eventing study by Kearsley et al. (2008) found an increase of the effect of age (better performance) the older the horse became for the intermediate and advanced levels. The differences in that study could depend on an increase of environmental effects (rider, training) or the difference in trait recordings. Viklund (2010) found an increase in heritability with increased age for show jumping and dressage in the SWB using the same method as in this study of accumulated results. This was explained by that older horses have more accumulated results than younger horses which result in a higher heritability. The increase in heritability with age could be because in those populations and disciplines the expression of genetic potential is higher at a more advanced level of competition, whereas the eventing population within the SWB is more affected by environmental factors than the show jumping and dressage horses (Viklund, 2010).

Heritabilities for the eventing traits were similar to those found by Ricard and Chanu (2001). However, the heritabilities for lifetime accumulated points and placings were found to be higher than the heritability for overall eventing competition estimated by Kearsley et al. (2008) but the points per placing heritability was lower in this study. The level of heritability found in this study for eventing competition traits was low (0.06-0.17) and is lower than found for show jumping and dressage in Sweden (Viklund, 2010). When compared to other studies, Aldridge et al. (2000) and Janssens et al. (2007) estimated lower heritabilities for show jumping than what was found in this study for eventing. Whereas, Huizinga and Van Der Meij (1989) and Gomez et al. (2006) found higher heritabilities for show jumping in their studies. The low heritability found by Kearsley et al., (2008) may be the result of using a sire model with incomplete pedigree records, whereas most other studies have applied animal models. It is hard to compare the results from different studies because of the use of different models, traits within eventing, and age groups. Pre-selection for competition horses can be a reason for the differences found between the studies. Competition horses are chosen based on recorded placing, pedigree, and other test results which can lead to a reduction of additive genetic variance and cause underestimated or lower heritabilities. Since every population is different there would be different pre-selection on the population tested even if the traits chosen were consistent.

Genetic correlations between results of different ages

The genetic correlations between results of different age groups were all positive and high (0.76 – 0.99). From this it can be concluded that the eventing horse information from an early age can be used to predict later eventing competition performance. The information would also include the horses at lower levels of eventing competition. This information can be used for breeding value estimation even though there are low heritabilities for the eventing traits. However, the lower genetic correlations were found between 4 to 6 years and lifetime but were still relatively high. The genetic correlation between 4 to 9 years and lifetime was close to one for one eventing trait and could mean that after 9 years of age there is less change in eventing performance. Also, after a horse competes a few times the better horses would stay in the eventing competition causing some selection in the population. These selected horses would get more attention and training possible causing part of the high levels genetic correlation (Viklund, 2010). Ricard and Chanu (2001) also found moderate to high correlations between results of a majority of the age groups in the French eventing population. Other studies have found high correlations between results achieved of different age groups for dressage and show jumping (Huizinga and van der Meij, 1989; Viklund, 2010).

Genetic correlations between different eventing traits

The genetic correlations were extremely high between the traits within eventing (0.97-0.99). The high correlations found in this study were expected since the three traits are related to the same results. Similar results were found in the study by Viklund (2010) for dressage and show jumping. Lifetime accumulated points would be preferred to measure the eventing performance because of the higher genetic additive genetic variation.

Genetic correlations between eventing and other riding sport disciplines

Show jumping and eventing had a moderate correlation of 0.44 whereas, dressage was found to not be correlated with eventing (-0.01). Ricard and Chanu (2001) found a lower genetic correlation for show jumping. When compared to dressage the show jumping correlation was similar to this study. Also, Ricard and Chanu (2001) found a correlation between eventing and dressage, whereas this study did not. In this study there were more horses that competed in both eventing and show jumping disciplines (47%) when compared to dressage (5%). It assumes that most horses compete in show jumping and dressage to become better at a specific discipline or phase. Also, jumping is included within two of the phases of eventing, whereas dressage is only one. Since dressage is a flat class, where movements and conformation are important, it could cause a lower correlation. Therefore with the results found in this study it can be stated that a good eventing horse is also a good show jumping horse.

Genetic correlations between eventing and young horse testing

Most of the tested traits within the RHQT were positively correlated with eventing. The two jumping traits had the highest correlations with eventing (0.34-0.41). There are two phases within eventing that include jumping and therefore it is understandable that the jumping traits are highly correlated to eventing. Also, the control of the horse within the jumping portions of the eventing competition would be important since the trials can be difficult as well as dangerous. Within the cross country phase the rider would need as much as control as possible since the slightest error could end in a disaster since the jumps are solid and will not fall. Rideability which also deals with responsiveness was weakly correlated to eventing (0.14).

The canter had also a moderate genetic correlation with eventing (0.34). The canter was also found as an important trait for show jumping and dressage (Viklund, 2010; Ducro et al., 2007; Gerber Olsson et al., 2000; Huizinga et al., 1990). The correlation found for canter was within the range found in other studies when compared with competition (Huizinga et al., 1990; Ducro et al., 2007). However, there was a positive correlation found for the walk (0.26) and a negative to no correlation was found for the trot (-0.06). These correlations were different than what was found for both the dressage and show jumping study done by Viklund (2010). In the study by Viklund (2010) for dressage the walk and trot were both highly correlated, whereas for show jumping the two traits had little to no correlation. It is possible that this walk and trot combination could be specific for eventing showing a combination of a dressage and show jumping type horse. The results found in this study indicate that the four traits (jumping temperament and technique, canter, and walk) are good predictors for later eventing performance. It does need to be stated that the standard errors were still rather high for these estimates and should be taken into account. The uses of early performance tests have also been found to help predict later performance at competition in other disciplines (Viklund, 2010; Ducro et al., 2007).

Genetic trend of eventing

There is an increase in the EBVs for the eventing population when using lifetime eventing points. The increase that started in the early 1980's was also found for show jumping, dressage, and for the RHQT in the SWB population (Viklund, 2010). There is at this time no selection directly for eventing as there is for the disciplines show jumping and dressage but there is still an increasing trend for eventing. Since show jumping and jumping traits within the RHQT were found to be moderately correlated with eventing it is likely that selection for show jumping resulted in a correlated genetic response in eventing as well. It could be in the future that eventing may be selected for within itself, but would always be affected by the decisions made for the show jumping SWB population.

Further studies

The complete rankings are now reported to the Swedish Equestrian Federation. This has been changed recently since until 2007 only the top 25% of competition horses are included in the competition data. In the future, the trait recording will be more complete and less selected. The results of the phases of eventing however, are not reported individually. In the future this could be changed and used in other research since the scores are recorded at the show for the individual phases.

When there is more information included in the eventing population it would be interesting to see a more precise genetic trend with show jumping to have a better understanding of the correlation between the two disciplines. It would also be beneficial to redo the bivariate analysis with the Young Horse Test for 3-year-olds when more of the young horses have had the opportunity to participate in eventing to see if information gained at this early age could also show later eventing performance like the RHQT information.

A further study could also be done to show the relationship of thoroughbreds in the SWB population and their role in the production of eventing horses.

Conclusions

- Heritability for eventing traits is low but clearly above zero and it can be concluded that eventing traits are heritable.
- High correlations were found within the three traits (lifetime points, lifetime placing, and lifetime points per placing) of eventing. However, lifetime points showed the highest genetic variation and are recommended for use in genetic analyses.
- The high genetic correlations between results achieved at different ages indicate that the eventing information from an early age can be used to predict later eventing competition performance.
- The moderate genetic correlations between eventing and show jumping and between eventing and RHQT traits indicate that eventing performance can be improved by selection of show jumping horses. The genetic trend also proves this.

- It would be possible to provide EBVs of stallions for eventign, but it is questionable how efficient these EBVs can be used.

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- Friends and Family

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