Genetic correlations between competition traits and traits scored at breeding field-tests in Icelandic horses

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Abstract

Relationships between breeding field-test traits and competition traits were studied to investigate whether the latter could be usefully included in the genetic evaluation of Icelandic horses. The current method of genetic evaluation is based on records from breeding field-tests only. The breeding field-test data included 16401 individual records of Icelandic horses evaluated in 11 countries during 1990–2005. Competition results included 18982 records of 3790 horses competing in sport and geðinga competitions in Iceland and Sweden during 1998–2004. In the breeding field-tests, eight conformation traits and eight riding ability traits were scored; height of withers was also recorded. These traits were analysed together with the competition traits tölt(comp), 4-gait, 5-gait and pace test, in bivariate analyses. Animal models were used; the fixed effects for breeding field-test traits included sex by age interaction and country by year interaction. For the competition traits the model included fixed effects of sex, age and event, and a random permanent environmental effect. Estimated heritabilities and genetic correlations for breeding field-test traits were consistent with earlier results; heritabilities ranged from 0.20 to 0.67, and moderate to high genetic correlations were estimated between many of the riding ability traits, and between riding ability traits and some conformation traits. The estimated heritabilities for competition traits were about 0.20, and genetic correlations between competition traits varied from −0.12 to 1.00.

In general, high genetic correlations were estimated between breeding field-test riding ability traits and competition traits. Moderately positive genetic correlations were found between some breeding field-test conformation traits and competition traits. Competition traits add information relating to the breeding goal of the Icelandic horse; they should therefore be added to genetic evaluation in future.

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1. Introduction

Icelandic horses, noted for their multi-gaited ability and excellent temperament, are kept as riding horses throughout Western Europe and North-America. More than 200 000 are registered on the global database Worldfengur, and over 25 000 have a recorded breeding field-test judgment (Árnason et al., 2006). In the present paper, for convenience, we shall call breeding traits measured in field-tests ‘breeding field-test traits. The breeding assessment system for Icelandic horses is available online at www.sciencedirect.com
international. Eighteen countries are members of the International Federation of Icelandic Horse Associations (FEIF), which oversees both the breeding assessment system (FIZO) and the competition (sport) assessment system (FIPO).

The official breeding goal for the Icelandic horse is described in Icelandic horse breeding (FEIF, 2004a). In general terms, this document states that the conformation of the horse should be both well suited for riding and aesthetically appealing. The horse should have five good gaits and an excellent temperament. Other less breed-specific traits such as health, fertility and size are also defined in the breeding goal.

Breeding horses, which are aged four years or older, are assessed at breeding field-tests, where stallions, mares, and a few geldings, are evaluated in various age-classes. Eight conformation traits (head; neck, withers and shoulders; back and hindquarters; proportions; leg quality; leg stance; hooves; mane and tale) and seven riding ability traits (walk; tölt; trot; pace; gallop; spirit; general impression) are scored, weighted and combined to provide a total score. Various body measurements, e.g. height of withers, are also recorded at breeding field-tests.

Today, genetic evaluations of the Icelandic horse are based on records from breeding field-tests of Icelandic horses run in 11 countries. A multi-trait animal model is used in the evaluations. The most recent genetic analysis of the breeding field-test traits was presented by Árnason and Sigurdsson (2004).

Special competitions for Icelandic horses have been popular in Europe for many years. The horses are ridden in various gaits on an oval track in so-called sport and gæðinga competitions, or on a straight track in the sport-competition discipline pace test and in pace racing competitions.

Genetic parameters for Icelandic horse competition traits have recently been estimated by Albertsdóttir et al. (in press) where use of combined traits (combinations of similar competition traits) and one original competition trait (the pace test) in a genetic evaluation was found to be promising. Although competition performance is not directly specified in the breeding goal for Icelandic horses, good competition horses are considered very valuable. There is, therefore, a good case for including competition traits in the genetic evaluation of Icelandic horses. This inclusion will require knowledge of the relationships between competition traits and traits scored in breeding field-tests.

Several studies have been made of the correlations between results in stallion performance tests or young horse competitions for Warmblood riding horses (in dressage and jumping) and competition results (Wallin et al., 2001; Thorén-Hellsten et al., 2006). Estimated genetic correlations between dressage-related traits in early testing and later results in dressage competition ranged from 0.20 to 0.88. Similarly, genetic correlations between jumping-related traits and results in show jumping ranged from 0.74 to 0.88.

To date similar studies have not been conducted with Icelandic horses. The aim of this study was therefore to estimate genetic correlations between traits scored at breeding field-tests and competition traits for the Icelandic horse.

2. Materials and methods

2.1. Data description

2.1.1. Breeding field-test data

Records from breeding field-tests were collected from the global database WorldFengur (www.worldfengur.com). The data included 16 401 records from horses tested between 1990 and 2005, in 11 countries (Iceland, Austria, Denmark, Finland, Germany, Great Britain, Norway, Sweden, Switzerland, The Netherlands, and the USA). Where a horse had been scored more than once at breeding field-tests, the highest total score for that animal was used; and a full record for each animal comprised 16 traits judged in the breeding field-test, along with height of withers. In Table 1 the number of observations, means, ranges, skewness and kurtosis for each of the 17 traits are presented. Four of the traits (height of withers, mane and tail, walk and slow tölt) have fewer observations as these traits have only been recorded over the last few years. The pace trait is shown twice in the table, because genetic analyses were performed both on ‘all pace records’ data and on ‘pace records scoring ≥ 5.5’ data.

2.1.2. Competition data

Competition data for horses registered on the WorldFengur database were collected (in Iceland) from The National Association of Riding Clubs and (in Sweden) from The Swedish Icelandic horse association. The data from the two countries was merged and included, after editing, 18 982 records from 3790 horses competing in 7 disciplines at 379 separate events. Details of the data-editing are described in Albertsdóttir et al. (in press).

2.1.3. Pedigree information

Relevant pedigree information from the international Icelandic horse database covered 10 generations and related to 30198 individual horses in total. The
pedigrees of all of the horses in the WorldFengur database can be traced back to Icelandic founders (Árnason et al., 2006).

2.2. Description of breeding field-test traits used in the current genetic evaluation

Stallions, geldings and mares are judged in four different age-classes: 4, 5, 6 and >6 years of age. Body measures and conformation scores are recorded before the riding ability traits are demonstrated on a straight track. The individual traits are weighted together in a total score in which conformation traits weigh 40% and riding ability traits weigh 60%. All traits are judged on a scale from 5 to 10 (best), except for height of withers, which is measured in cm (FEIF, 2004a).

The traits are briefly described below. A detailed description of the judging scale and instructions can be found at www.feif.org, where the rules for Icelandic horse breeding (FIZO) are reproduced (FEIF, 2004a).

2.2.1. Conformation traits

Height of withers is measured at the highest point of the withers, and mane and tail are judged for length and thickness. Other conformation traits – head; neck, withers and shoulders; back and hindquarters; proportions; leg quality; leg stance; and hooves – are scored for both aesthetic appearance and assumed functionality in relation to health and riding ability in accordance with a detailed judging scale and instructions in FIZO (FEIF, 2004a).

2.2.2. Riding abilities

Walk, slow tölt, tölt, trot, pace, and gallop are judged in respect of quality of gait; correctness, rhythm, appearance, suppleness and energy. These gaits should have the correct beat, and the horse should be able to perform at the appropriate speed. Scores are also given for slow tölt and canter; these indirectly influence the judgment of tölt and gallop. Spirit is a measure of the temperament and willingness of the horse, which should be easy to ride and to handle, and should require very little encouragement to perform at its best. General impression is a measure of form under rider. Here the horse should be impressive and elegant with attractive movements, good head carriage and charm.

Genetic analyses were performed both on ‘all pace records’ data and on ‘pace records scoring ≥ 5.5’ data. Pacing ability is a threshold trait, i.e. one showing...
continuous variation above a certain threshold (Árnason and Sigurdsson, 2004). Thus horses obtaining 5.0 for pace do not show pace. It is assumed that these horses belong to two different sub-populations. One is occupied by horses that are true four-gaiters (tölt, trot, walk and gallop) and do not have any genetic ability to pace. The other is made up of horses that have been trained as four-gaiters and therefore not shown in pace, although they might have the genetic ability for it. Training of this last kind is not uncommonly preferred. It is widely believed that pace training can impair the performance of tölt. Given how valuable the tölt is, many horses are, as a result, not trained in pace and are only shown as four-gaiters. Pace records equal to five are therefore not true measurements of pacing ability. Their inclusion can generate biased estimates of genetic parameters.

2.3. Description of competition traits

Sport and gæðinga competitions are the two main types of competition for Icelandic horses. They are performed on oval tracks and on a straight track (pace test). Each type of competition involves several disciplines in which the horses are ridden in the various gaits. In a previous genetic analysis of competition data for Icelandic horses (Albertsdóttir et al., in press), combined traits were formed from original competition disciplines so as to describe competition performance ability in a simpler manner. These combined traits were also more stable in statistical analyses. A detailed description of the judging scale and instructions for original competition traits is available at www.feif.org, where the rules for Icelandic horse competitions (FIPO) are reproduced (FEIF, 2004b, 2005). A short description of the competition traits analysed in the present study is provided in Albertsdóttir et al. (in press).

Original scores given for gæðinga competition traits range from 5 to 10. For sport competition traits they range from 0 to 10. For the combined traits tölt(comp), 4-gait and 5-gait scores from original traits were standardised to an approximately zero mean with a standard deviation of one. The combined traits and PP1 were found to be normally distributed on the basis of estimated skewness and kurtosis. Table 1 shows the number of observations, means, ranges, skewness and kurtosis for all traits.

2.4. Statistical model and the estimation of genetic parameters

2.4.1. Breeding field-test traits

The model used in the current genetic evaluation was also used for breeding field-test traits (Árnason and Sigurdsson, 2004):

\[ y_{ijk} = \text{year}_i \times \text{country}_i + \text{age}_j \times \text{sex}_j + \text{animal}_k + e_{ijk} \]

where \( y_{ijk} \) is the score of each breeding test trait of \( k \)th horse, \( \text{year}_i \times \text{country}_i \) is the fixed effect of year by country interaction of \( i \)th year \( \times \) country \((i=1,...,37)\), \( \text{age}_j \times \text{sex}_j \) is the fixed effect of the age by sex interaction...
of \( j \)th age\_sex (\( j=1,...,8 \)), animal\(_k\) is the random additive genetic effect of the 4th horse \( \sim ND(0, A\sigma^2_a) \), \( A \) being the numerator relationship matrix among horses, and \( e_{ijk} \) is the random \( \sim ND(0, I\sigma^2_e) \) residual effect. The number of the subclass year\_country is smaller than sixteen (years) by eleven (countries); breeding field-testing has not been judged over the whole period 1990–2005 in all countries.

### 2.4.2. Competition traits

In this study the model used for analysis of the competition traits was the same as that used in the previous study of genetic parameters by Albertsdóttir et al. (in press), which included fixed effects of age, sex and the event and random effects of the animal and permanent environmental effects.

### 2.4.3. Estimation of (co)variances

Genetic (co)variances were estimated using the Jensen and Madsen (2000) DMU-package. Analyses were undertaken with univariate and bivariate models. (Co)variances were estimated using the average information algorithm for REML, and asymptotic standard errors of (co)variances components were computed from the inverse average information matrix. Heritabilities were calculated as \( \sigma^2_a/(\sigma^2_a+\sigma^2_pe+\sigma^2_e) \) and repeatabilities as \( (\sigma^2_a+\sigma^2_pe)/(\sigma^2_a+\sigma^2_pe+\sigma^2_e) \). Standard errors of the heritabilities and repeatabilities were computed with the Taylor series expansion (Albertsdóttir et al., in press). Residual correlations between breeding field-test traits and competition traits were constrained to zero as almost no horses participated in both the competitions and the breeding field-test.

### 3. Results

#### 3.1. Breeding field-test traits

Estimated heritabilities for breeding field-test traits ranged between 0.20 and 0.67 (Table 1), with the highest values for height of withers, pace, and mane and tail. Genetic and phenotypic correlations between different breeding field-test traits are set out in Table 2. Moderate genetic correlations were generally estimated between different conformation traits; height of withers, neck, withers and shoulders, back and hindquarters, and proportions. These conformation traits often showed moderate genetic correlations with the riding ability traits slow tölt, tölt, gallop, spirit, and general impression. In general, other conformation traits were not related to riding ability traits. Moderate to high genetic correlations were estimated between most of the riding ability traits.

### 3.2. Competition traits

The estimated heritabilities of competition traits in univariate analyses were all close to 0.20. The estimated heritabilities of competition traits from bivariate analyses with breeding field-test traits ranged between 0.18 and 0.37 for tölt(comp), 0.21 and 0.44 for 4-gait, 0.20 and 0.42 for 5-gait, and 0.17 and 0.24 for PP1. Estimated correlations within combined traits (not shown in the table, but see Albertsdóttir et al., in press) ranged between 0.62 and 0.90; and between PP1 and the combined traits values from −0.12 (4-gait) to 1.00 (5-gait) were observed.

### 3.3. Correlations between breeding field-test traits and competition traits

In general, moderately high genetic correlations were estimated between competition traits and the breeding field-test conformation traits; neck, withers and shoulders, back and hindquarters, proportions, and hooves (Table 3). The competition traits tölt(comp), 4-gait and 5-gait showed high positive genetic correlations with the breeding field-test traits slow tölt, tölt, trot, gallop, spirit, and general impression (Table 3). The competition traits 4-gait and 5-gait displayed a moderately high genetic correlation with the breeding field-test trait walk. Pace in the breeding field-test was highly correlated with 5-gait and pace test (PP1) in competition. Moderately high

<table>
<thead>
<tr>
<th>Breeding field-test traits</th>
<th>Competition traits</th>
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<tbody>
<tr>
<td></td>
<td>Tölt(comp)</td>
</tr>
<tr>
<td>Height on withers</td>
<td>0.15</td>
</tr>
<tr>
<td>Mane and tail</td>
<td>0.08</td>
</tr>
<tr>
<td>Head</td>
<td>0.28</td>
</tr>
<tr>
<td>Neck, withers and shoulders</td>
<td>0.52</td>
</tr>
<tr>
<td>Back and hindquarters</td>
<td>0.41</td>
</tr>
<tr>
<td>Proportions</td>
<td>0.39</td>
</tr>
<tr>
<td>Leg quality</td>
<td>0.06</td>
</tr>
<tr>
<td>Leg stance</td>
<td>−0.03</td>
</tr>
<tr>
<td>Hooves</td>
<td>0.52</td>
</tr>
<tr>
<td>Walk</td>
<td>0.23</td>
</tr>
<tr>
<td>Slow tölt</td>
<td>0.93</td>
</tr>
<tr>
<td>Tölt</td>
<td>0.96</td>
</tr>
<tr>
<td>Trot</td>
<td>0.91</td>
</tr>
<tr>
<td>Pace (all records)</td>
<td>−0.14</td>
</tr>
<tr>
<td>Pace (records ≥ 5.5)</td>
<td>0.38</td>
</tr>
<tr>
<td>Gallop</td>
<td>0.93</td>
</tr>
<tr>
<td>Spirit</td>
<td>0.94</td>
</tr>
<tr>
<td>General impression</td>
<td>0.88</td>
</tr>
</tbody>
</table>

All standard errors were \( \leq 0.20 \).
genetic correlations were estimated between the competition trait pace test (PP1) and the breeding field-test traits tölt, spirit, and general impression.

Standard errors of the genetic correlations between the competition trait pace test (PP1) and the breeding field-test traits were generally higher, than they were in other genetic correlations (most S.E. ≤ 0.10) between competition traits and breeding field-test traits.

4. Discussion

Competitions for Icelandic horses are popular, and good competition horses are, along with breeding horses, the most valuable individuals within the Icelandic horse breed. Estimated genetic correlations between breeding field-test traits and competition traits confirm that similar qualities are sought in both breeding horses and competition horses. The moderate genetic correlations between competition traits and some of the breeding field-test conformation traits (neck, withers and shoulders; back and hindquarters; proportions; hooves) show that gaiting ability, spirit, and general impression are related to sound conformation in the horses. Moderate to high favourable genetic correlations between most riding ability traits assessed at breeding field-tests, on the one hand, and competition traits, on the other, show that performance ability is evaluated similarly in both breeding field-tests and competitions.

The results of the present study of relationships between breeding field-test traits and competition traits accord with similar studies of the relationship between the results of early tests and those of later competitions in Warmblood riding horses (Wallin et al., 2001; Thorén-Hellsten et al., 2006).

The estimated heritabilities for breeding field-test traits and the correlations between breeding field-test traits in this study were consistent with earlier results obtained by Árnason and Sigurdsson (2004). Árnason and Sigurdsson estimated genetic parameters on the basis of a data-set which was similar to, and overlapped with, that used in the present study. Breeding field-test records from 1990–2003 were included, and a multiple-trait animal model was used for thirteen of the traits; and univariate models for height of withers, mane and tail, walk and slow tölt. The present study shows that genetic parameters on pace change considerably depending on whether all pace records or only records with pace scores ≥ 5.5 are analysed. The estimated heritability of pace in analyses in which horses not showing pace (i.e. with pace scores equal to 5) were excluded was lower than that obtained when pace scores ≥ 5.5 alone were analysed; and genetic correlations between pace and other riding ability traits were moderately to highly positive instead of being for the most part negative. The same pattern was observed when pace was analysed together with competition traits. This is in accordance to earlier results indicating that, when all records are included, the estimated heritability of pace tends to be overestimated and genetic correlations are downwardly biased (Árnason and Sigurdsson, 2004).

Albertsdóttir et al. (in press) analysed genetic parameters for competition traits. They showed that competition traits are suitable for inclusion in a genetic evaluation. However, problems associated with selection arise when competition traits are used in genetic evaluations. Genetic parameters can be assumed to be biased, because the genetic variation of the horses is not fully expressed; the sample of competing horses is hardly random, as considerable selective activity dictates which horses are presented at competitions. Results from the present study show that the estimated heritability of competition traits increases when these traits are analysed together with highly correlated breeding field-test traits. This is an indication that the effect of selection (in reducing genetic variance in competition data) decreases when competition data is analysed simultaneously with breeding field-test data. To avoid or diminish the effect of this selection bias in a genetic evaluation using competition data, both sets of data from breeding field-tests and competitions should be included in a joint genetic evaluation (Koerhuis and van der Werf, 1994; Thorén-Hellsten et al., 2006). Furthermore, if competition data were to be included in the genetic evaluation of Icelandic horses, a new information source would come to be utilised, since many competition horses are geldings that are seldom evaluated in breeding field-tests. In all probability, this additional information would increase the reliability of genetic predictions.

5. Conclusions

The results of the present study confirm that, in the Icelandic horse, competition traits and riding ability traits from breeding field-tests are closely correlated. The inclusion of competition traits in genetic evaluation would be beneficial, because competition traits add information relating to the horse’s breeding goal and reduces bias due to selection. Furthermore, studies of the implementation of competition traits in the current method of genetic evaluation, the effect of this upon reliability and genetic progress, and also, preferably, the economic benefits secured, should be carried out. Further studies should also take upon more exact definition
of the breeding objective as the relevance of competition traits relates to the definition of the breeding objective.

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