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# Genetic analysis of competition traits in Icelandic Horses

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# Aim of the study

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**Explore the basis for including competition traits in the genetic evaluation of the Icelandic horse**

The genetic evaluation is currently based on records from breeding field-test traits

# Breeding goal

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- The Icelandic horse should have five good gaits and an excellent temperament
- Conformation should be well suited for riding and aesthetically appealing



# Breeding objectives

- Detailed description of traits measured in breeding field tests with relative weightings

Conformation		Ridden abilities/gaits	
Head	3%	Tölt	15%
Neck, withers & shoulders	10%	Trot	7.5%
Back and hindquarters	3%	Pace	9%
Proportions	7.5%	Canter/gallop	4.5%
Leg quality	6%	Spirit	12.5%
Leg stance	3%	General impression	10%
Hooves	6%	Walk	1.5%
Mane and tail	1.5%		
<b>Total:</b>	<b>40%</b>		<b>60%</b>

# Estimation of breeding values

- BLUP method
- Includes 17 traits
  - The 15 traits judged in field-tests
  - Total score
  - Height of withers
- Horses ranked according to total score
- International genetic evaluation
  - Since 2005
  - 11 countries
- Registration on WorldFengur
  - Unique ID-number
  - Breeding field-test records
  - Estimated breeding values
  - Pedigree and progeny information
  - Breeder and owner (history)
  - Colour, identification marks
  - DNA sequences
  - Health records



# Back to the aim of the study

## - reasons

- Competitions are popular
  - Good competition horses are valuable and much sought after
  - Valuable traits
  - New information source
    - Information on many new individuals
  
- Breeding standards for Icelandic horses
  - A multi-gaited riding horse for pleasure riding and sport competitions suited for adults and children
  
- Selection of horses
  - Based on estimated breeding values
    - Records from breeding field-tests
    - 17 traits being the goal traits
    - What about genetic progress



# Genetic response

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- To obtain the maximum genetic response
  - The breeding objectives have to be well defined and to include details of **all** the traits that breeders wish to improve by genetic selection

$$\Delta G = \frac{i * R(TI) * SD_A}{L}$$

- $i$  = Selection intensity
- $R(TI)$  = Accuracy in breeding estimation - Connection between the true breeding value and the criteria that the selection (index) is based on
- $SD_A$  = Genetic variation of trait that are included in the breeding goal
- $L$  = Generation interval

# Competition traits as goal traits?

- Can genetic evaluation be based on competition traits?
  - Genetic analysis on competition data
    - i.e. can genetic evaluation be based on competition traits
  - Genetic correlations between competition traits and breeding field-test traits
    - i.e. can competition traits be included in current genetic evaluation

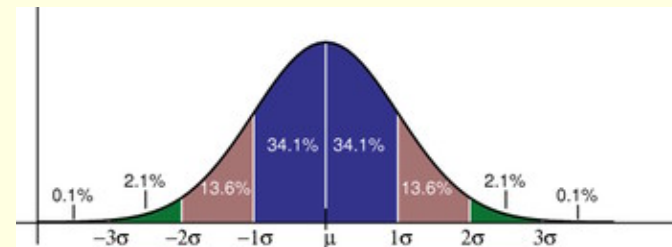


# Assumptions - Theory

- Quantitative traits - Continuous traits
  - Controlled by many underlying genes
  - Under significant environmental influence

$$P = G + E \rightarrow V_P \approx V_A + V_D + V_E + V_I$$

- Resemblance between relatives
  - Used to estimate which proportion of the total phenotypic variance is explained by each component
- The distribution is normal
  - 68% of the population/sample is within 1 standard deviation
  - 95% within 2 standard deviation
  - 99.7% within 3 standard deviation
  - Skewness – asymmetry around the mean – should be 0
  - Kurtosis – peakedness of the curve – should be 0



# Theory - definitions

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- Heritability ( $h^2$ )

- The proportion of the total (phenotypic) variation that is explained by the genetic variation

$$h^2 = \frac{V_A}{V_p}$$

- Correlation

- Indicates the strength and direction of a linear relationship between two random variables
- Genetic correlation; some genes have effect on various traits

$$\text{Genetic\_correlation} = \frac{\text{Cov}(A_1, A_2)}{\sqrt{V_{A_1} * V_{A_2}}}$$

# Genetic analysis of competition data in Icelandic horses

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- Competition data provided by
  - The National Association of Riding Clubs in Iceland
    - MótaFengur
  - The Swedish Icelandic Horse Association
  
- The data
  - from the two countries were merged on the basis of
    - strong genetic correlations between similar competition traits
    - similar means and standard deviations
  - included results from sport and gæðinga competitions
    - from the period 1998 to 2004
    - with a total of 18 982 records
    - of 3790 horses
    - in 379 different events
  
- An insufficient quantity of data was available from pace racing competitions
  
- Pedigree information
  - 10 generations with 12 324 individuals

# Competition traits

- Total score – repeated measurements
- Sport competitions
  - International sport competition rules (FIPO)
  - Tölt (T1), Loose-rain tölt (T2), Four-gait (V1), Five-gait (F1), Pace test (PP1)
- Gæðinga competitions
  - Icelandic gæðinga-keppni rules (Appendix to FIPO)
  - Four-gait (B-class), Five-gait (A-class)
- Combined traits
  - Comparable disciplines combined where strong genetic correlation was estimated
    - Tölt(comp) a combination of the tölting disciplines; T1 and T2
    - 4-gait a combination of the four-gaited disciplines; V1 and B-class
    - 5-gait a combination of the five-gaited disciplines; F1 and A-class
  - Scores were standardized → standard normal deviation
    - Mean of zero
    - Standard deviation of one



# Material

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Traits	No. obs	No. horses	Mean	SD	Min	Max	Skewness	Kurtosis
<i>Sport competition</i>								
Tölt test (T1)	6279	2102	5.41	0.87	2.53	8.20	-0.08	-0.18
'Loose-rein' tölt (T2)	1487	517	5.39	0.82	2.60	7.73	-0.13	0.00
Four-gait test (V1)	5768	1938	5.40	0.72	3.10	7.67	-0.18	-0.02
Five-gait test (F1)	3178	1069	5.01	0.97	2.13	7.37	-0.23	-0.52
Pace test (PP1)	1481	606	4.37	2.19	0.17	9.72	0.06	-0.99
<i>Gæðinga competition</i>								
B-Class	451	385	8.06	0.31	6.85	8.73	-0.92	1.57
A-Class	338	279	8.01	0.35	6.98	8.85	-0.78	0.26

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# Material

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Trait	T1	T2	V	F	PP1	B-Class	A-Class
T1	<b>6279</b>						
T2	13	<b>1487</b>					
V	4098	267	<b>5768</b>				
F	497	686	14	<b>3178</b>			
PP1	144	269	22	939	<b>1481</b>		
B-Class	87	0	0	0	0	<b>451</b>	
A-Class	7	0	0	0	0	1	<b>338</b>

# Statistical analysis - models

$$y_{ijklm} = age_i + sex_j + event_k + level_l + animal_m + pe_m + e_{ijklm}$$

$$y_{ijklm} = age_i + sex_j + event_k + animal_m + pe_m + e_{ijklm}$$

- Fixed effects that were statistically significant
  - Age, sex and event on all competition traits
  - Level of discipline for four of the original sport traits
    - T1, T2, V1 and F1
  
- Random effects
  - The random additive genetic effect of the horse
  - The random permanent environmental
  - The random residual effect



# Estimation of genetic parameters

- (Co)variance components estimated
  - In univariate and bivariate analyses

- Heritabilities were calculated as

$$\sigma_a^2 / (\sigma_a^2 + \sigma_{pe}^2 + \sigma_e^2)$$

- values between 0 and 1

- Repeatabilities were calculated as

$$(\sigma_a^2 + \sigma_{pe}^2) / (\sigma_a^2 + \sigma_{pe}^2 + \sigma_e^2)$$

- values between 0 and 1

- Correlations

- Genetic, permanent environmental and residual
  - values between -1 and 1





## Results

Heritabilities<sub>(SE)</sub>,  
repeatabilities<sub>(SE)</sub> and  
variance components

Trait	$h^2$	Repeatability	$\sigma_a^2$	$\sigma_{pe}^2$
<i>Sport competition</i>				
T1	0.18 <sub>0.05</sub>	0.63 <sub>0.01</sub>	0.09	0.23
T2	0.23 <sub>0.14</sub>	0.68 <sub>0.03</sub>	0.13	0.26
V1	0.19 <sub>0.05</sub>	0.64 <sub>0.01</sub>	0.07	0.16
F1	0.19 <sub>0.07</sub>	0.48 <sub>0.02</sub>	0.12	0.18
PP1	0.21 <sub>0.11</sub>	0.42 <sub>0.03</sub>	0.80	0.76
<i>Gæðinga competition</i>				
B-Class	0.33 <sub>0.21</sub>	0.57 <sub>0.08</sub>	0.03	0.02
A-Class	0.35 <sub>0.23</sub>	0.51 <sub>0.11</sub>	0.04	0.02
<i>Combined traits<sup>a</sup></i>				
Tölt(comp) <sup>b</sup>	0.19 <sub>0.05</sub>	0.67 <sub>0.01</sub>	0.16	0.40
4-gait <sup>b</sup>	0.22 <sub>0.05</sub>	0.67 <sub>0.01</sub>	0.17	0.36
5-gait <sup>b</sup>	0.22 <sub>0.07</sub>	0.56 <sub>0.02</sub>	0.17	0.26

# Results on heritabilities and repeatabilities

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- Sport competition and combined traits
  - 20% (0.18 – 0.23)
  - SE ranging between 0.05 – 0.14
- Gæðinga competition traits
  - 30-35% (0.33 – 0.35)
  - SE ranging between 0.21 – 0.23
- Repeatabilities
  - 60% (0.42 – 0.68)
  - SE ranging between 0.01 – 0.11

Genetic correlations with SE as subscripts  
between sport- and gæðinga-competition traits from bivariate analyses

Trait	T1	T2	V1	F1	PP1	B-Cl.
T2	0.71 <sub>0.19</sub>					
V1	0.85 <sub>0.07</sub>	0.74 <sub>0.22</sub>				
F1	0.63 <sub>0.18</sub>	0.96 <sub>0.14</sub>	0.71 <sub>0.19</sub>			
PP1	0.43 <sub>0.24</sub>	0.10 <sub>0.41</sub>	-0.03 <sub>0.30</sub>	0.93 <sub>0.17</sub>		
B-Class	0.93 <sub>0.17</sub>	1.00 <sub>0.34</sub>	0.93 <sub>0.26</sub>	0.18 <sub>0.43</sub>	-0.42 <sub>0.42</sub>	
A-Class	0.84 <sub>0.33</sub>	0.50 <sub>0.54</sub>	0.50 <sub>0.35</sub>	0.94 <sub>0.25</sub>	0.97 <sub>0.49</sub>	0.43 <sub>0.51</sub>

Genetic correlations with SE as subscripts  
between combined traits from bivariate analyses

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	Tölt(comp)	4-gait	5-gait
4-gait	0.90 <sub>0.05</sub>		
5-gait	0.74 <sub>0.14</sub>	0.62 <sub>0.18</sub>	
PP1	0.38 <sub>0.24</sub>	-0.12 <sub>0.28</sub>	1.00 <sub>0.13</sub>

# Results on genetic correlations

- Sport competition traits
  - 0.63 – 0.96
    - SE ranging between 0.07 – 0.49
- Gæðinga competition traits
  - 0.43
    - SE as 0.51
- Gæðinga competition traits vs. Sport competition traits
  - 0.93
    - SE ranging between 0.17 – 0.54
- Combined traits
  - 0.62 – 0.90
    - SE between 0.05–0.18 (0.28)



# Conclusions

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- Inclusion of competition traits in the genetic evaluation
  - could bring considerable economic benefits
    - good competition horses are valuable
    - much sought-after by riders
- Usage of competition traits would involve
  - utilization of a new information source
  - as a large number of competition horses are geldings
    - which seldom participate in breeding field tests.

# Problem!

## Selection in competition data

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- Pre-selection →
  - Only records from specific disciplines
  - Disqualified horses are ignored
  
- Selected animals make up a sample that does not reflect the true variance of the population →
  - reduction in the additive genetic variance
  - Competition horses are assumed to be selected individuals
    - causes bias in estimated genetic parameters
    - as decrease in the estimates of heritabilities
  - Chosen as considered winners
    - Older and more thoroughly trained
  - Better riders pair with better horses?

# Conclusions

- Combined traits are the most promising to use in genetic evaluations
  - More stable in statistical analyses
    - Heritability and genetic correlations estimated with greater precision
- Giving more significant and useful pattern of results
- Describe competition traits in a simpler manner
  - The aptitude of competing horse in
    - tölt (tölt(comp))
    - four-gait (4-gait)
    - five-gait (5-gait)
- May be more readily accepted by the breeders and trainers
- The pace test (PP1) could be used in the genetic evaluation
  - to describe the competition aptitude of the pace horse
- A sufficient quantity of competition data needs to be made available in the future
  - data collection should be standardized

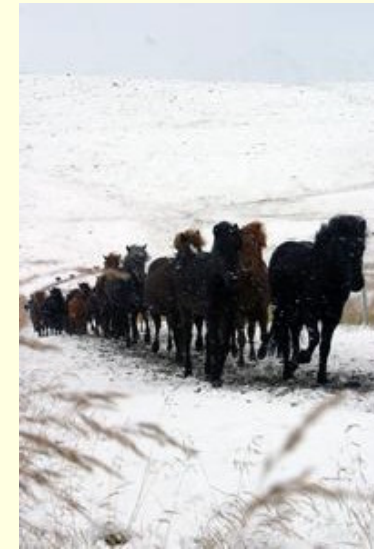


# Genetic correlations between competition traits and traits scored at breeding field-tests in Icelandic horses

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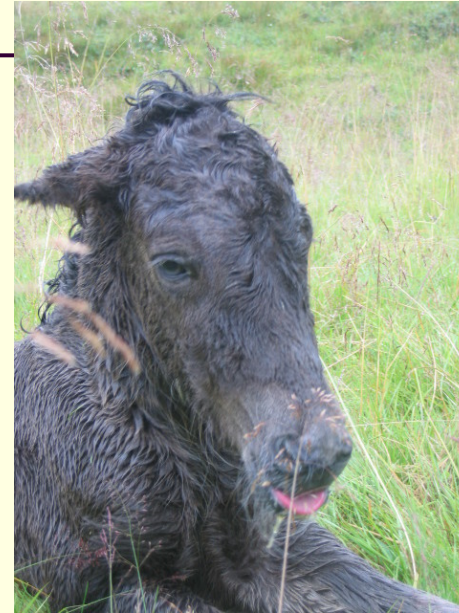
## Material

- Competition data
  - Same data-set as before
  - Combined traits and pace test
    - Tölt(comp); 4-gait; 5-gait; PP1
    - 18 982 records of 3790 horses
- Breeding field-test data
  - 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; the USA
- Pedigree information
  - 10 generations with 30 198 individuals



# Breeding field-tests

- Age classes: 4; 5; 6; >6 years old
- Measurement of various body parts
  - E.g. height of withers
- Conformation traits
  - 8 traits including head; neck, withers and shoulder; back and hindquarters; proportions; leg quality; leg stance; hooves; mane and tail
- Riding ability traits
  - 7 traits including; tölt (slow tölt); trot; pace; gallop (canter); general impression; spirit; walk
  - On a straight track
  - Second assessment (overview show)



Traits	No. obs	Mean	Range	Skewness	Kurtosis
<i>Breeding field-test traits</i>					
Height of withers	14 817	137.52 <sub>3.69</sub>	114–152	0.16	0.18
Mane and tail	8 431	7.49 <sub>0.73</sub>	5.0–10.0	0.13	-0.01
Head	16 401	7.59 <sub>0.51</sub>	5.5–9.5	0.11	0.01
Neck, withers, shoulders	16 401	7.92 <sub>0.43</sub>	6.0–9.5	-0.03	0.33
Back and hindquarters	16 401	7.70 <sub>0.56</sub>	6.0–9.5	0.10	-0.10
Proportions	16 401	7.64 <sub>0.52</sub>	5.5–9.5	-0.17	0.11
Leg quality	16 401	7.71 <sub>0.54</sub>	6.0–10.0	0.11	-0.01
Leg stance	16 401	7.54 <sub>0.51</sub>	6.0–9.5	0.08	0.03
Hooves	16 401	7.84 <sub>0.54</sub>	5.5–10.0	-0.12	0.23
Slow toelt	6 485	7.66 <sub>0.71</sub>	5.0–10.0	-1.11	2.50
Walk	9 014	7.61 <sub>0.70</sub>	5.0–10.0	-0.59	0.60
Tölt	16 401	7.74 <sub>0.67</sub>	5.0–10.0	-0.55	0.65
Trot	16 401	7.60 <sub>0.72</sub>	5.0–10.0	-0.68	1.19
Pace (all records)	16401	6.45 <sub>1.29</sub>	5.0–10.0	0.31	-1.20
Pace (records ? 5.5)	11 150	7.14 <sub>1.00</sub>	5.5–10.0	0.06	-0.89
Gallop/Canter	16 401	7.80 <sub>0.60</sub>	5.0–9.5	-0.28	0.12

# Models

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## ■ Competition data

$$y^{ijklm} = age^i + sex^j + event^k + animal^m + pe^m + e^{ijklm}$$

- Same as was used in previous paper

## ■ Breeding field-test data

$$y^{ijk} = year\_country^i + age\_sex^j + animal^k + e^{ijk}$$

- Same as is used in current genetic evaluation
- Two fixed effects
  - Year by country interaction
  - Age by sex interaction

# Estimation of genetic parameters

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- (Co)variance components estimated using
  - In univariate and bivariate analyses

- Heritabilities were calculated as

$$\sigma_a^2 / (\sigma_a^2 + \sigma_{pe}^2 + \sigma_e^2)$$

- Repeatabilities were calculated as

$$(\sigma_a^2 + \sigma_{pe}^2) / (\sigma_a^2 + \sigma_{pe}^2 + \sigma_e^2)$$

- Correlations

- Genetic, residual and permanent environmental

- Residual correlations between sets of traits

- constrained to zero

- almost no horses participated in both competitions and breeding field-test



## Results

Heritabilities<sub>(SE)</sub>,  
additive genetic  
and residual  
variances  
estimated in  
single trait  
analyses

Breeding field-test traits	$h^2$	$\sigma_a^2$	$\sigma_e^2$
Height of withers	0.67 <sub>0.02</sub>	6.15	3.04
Mane and tail	0.46 <sub>0.03</sub>	0.22	0.25
Head	0.29 <sub>0.02</sub>	0.07	0.18
Neck, withers and shoulders	0.39 <sub>0.02</sub>	0.07	0.11
Back and hindquarters	0.29 <sub>0.02</sub>	0.08	0.20
Proportions	0.38 <sub>0.02</sub>	0.08	0.14
Leg quality	0.37 <sub>0.02</sub>	0.11	0.18
Leg stance	0.22 <sub>0.02</sub>	0.06	0.20
Hooves	0.36 <sub>0.02</sub>	0.10	0.18
Slow tölt	0.38 <sub>0.04</sub>	0.18	0.30
Walk	0.20 <sub>0.03</sub>	0.10	0.38
Tölt	0.39 <sub>0.02</sub>	0.16	0.25
Trot	0.38 <sub>0.02</sub>	0.18	0.30
Pace (all records)	0.58 <sub>0.08</sub>	0.94	0.67
Pace (records ? 5.5)	0.34 <sub>0.02</sub>	0.31	0.60
Gallop/Canter	0.36 <sub>0.02</sub>	0.12	0.22
Spirit	0.37 <sub>0.02</sub>	0.05	0.20

# Results on heritabilities

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- Breeding field-test traits
  - Ranging between 0.22 and 0.67
  - Most estimates around 0.38
  - Highest for height of withers, mane and tail
  - Lowest for walk and leg stance
- Competition traits
  - Estimated heritabilities on competition traits got higher when competition traits were analysed together with strongly correlated breeding field-test traits

Trait	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Height of withers		0.01	0.00	0.28	0.00	0.29	0.06	0.03	0.15	0.04	0.04	0.08	0.05	0.03	0.09	0.14	0.01
Mane and tail	0.04		0.20	0.12	0.07	0.08	0.12	0.01	0.05	0.05	0.02	0.05	0.02	0.04	0.04	0.07	0.07
Head	-0.07	0.26		0.30	0.12	0.22	0.03	0.04	0.04	0.11	-0.01	0.10	0.06	0.02	0.09	0.17	0.11
Neck, withers and shoulders	0.39	0.12	0.42		0.17	0.47	0.06	0.03	0.11	0.22	0.04	0.26	0.17	0.05	0.26	0.45	0.12
Back and hindquarters	-0.01	0.09	0.22	0.35		0.25	0.02	0.05	0.05	0.10	0.04	0.14	0.11	0.04	0.12	0.16	0.12
Proportions	0.44	0.12	0.30	0.69	0.39		0.02	0.00	0.12	0.17	0.07	0.17	0.11	0.07	0.19	0.27	0.13
Leg quality	0.08	0.22	0.04	0.12	0.02	0.04		0.02	0.12	0.04	0.06	0.06	0.07	0.00	0.07	0.06	0.03
Leg stance	0.02	-0.06	0.02	0.07	0.11	0.05	0.02		0.03	0.01	-0.01	0.04	0.04	0.03	0.04	0.05	0.04
Hooves	0.26	0.00	0.02	0.20	0.17	0.16	0.16	0.09		0.12	0.04	0.15	0.13	0.06	0.16	0.16	0.12
. Slow tölt	0.05	0.00	0.18	0.28	0.21	0.24	0.09	0.00	0.31		0.11	0.74	0.40	-0.04	0.42	0.66	0.46
. Walk	0.08	-0.02	0.00	0.00	-0.03	0.06	0.26	-0.21	0.12	0.11		0.16	0.22	-0.07	0.15	0.13	0.08
. Tölt	0.10	-0.05	0.10	0.32	0.24	0.22	0.02	0.01	0.25	0.92	0.18		0.52	-0.02	0.48	0.73	0.60
. Trot	0.03	-0.02	0.07	0.17	0.20	0.12	0.04	0.00	0.20	0.65	0.29	0.74		-0.12	0.39	0.50	0.43
. Pace (records ? 5.5)	0.03	0.04	0.09	0.10	0.19	0.08	0.04	0.06	0.24	0.21	-0.22	0.38	0.11		0.02	0.03	0.20
. Gallop	0.14	0.00	0.16	0.44	0.26	0.32	0.12	0.07	0.27	0.72	0.11	0.80	0.62	0.31		0.53	0.52
. Spirit	0.17	0.01	0.25	0.54	0.30	0.38	0.08	0.05	0.26	0.87	0.04	0.88	0.64	0.33	0.82		0.63
. General impression	-0.05	0.01	0.20	0.27	0.24	0.20	-0.01	0.06	0.27	0.61	-0.07	0.80	0.58	0.61	0.76	0.80	



# Summary

## Estimated genetic correlations between breeding field-test traits

- Conformation traits
  - Some moderate genetic correlations
    - neck, withers and shoulders; back and hindquarters; proportions; hooves
  - Otherwise weak genetic correlations
- Conformation vs. Riding ability
  - Moderate genetic correlations
    - Same conformation traits as before correlated to slow tölt; tölt; gallo; spirit; general impression
- Riding ability traits
  - Strong genetic correlations between most of the riding ability
  - Weak genetic correlation between most of the riding ability traits and walk



## Results

Genetic correlations<sub>(S.E.)</sub>  
between competition traits  
and breeding field-test  
traits from bivariate  
analyses

Breeding field-test traits	Competition traits			
	Tölt(comp)	4-gait	5-gait	PP1
Height on withers	0.15 <sub>0.09</sub>	0.15 <sub>0.09</sub>	0.14 <sub>0.10</sub>	0.38 <sub>0.15</sub>
Mane and tail	0.08 <sub>0.10</sub>	0.09 <sub>0.09</sub>	0.22 <sub>0.11</sub>	0.07 <sub>0.15</sub>
Head	0.28 <sub>0.09</sub>	0.23 <sub>0.10</sub>	0.24 <sub>0.11</sub>	-0.05 <sub>0.15</sub>
Neck, withers and shoulders	0.52 <sub>0.08</sub>	0.41 <sub>0.08</sub>	-0.05 <sub>0.18</sub>	0.29 <sub>0.14</sub>
Back and hindquarters	0.41 <sub>0.10</sub>	0.29 <sub>0.10</sub>	0.54 <sub>0.12</sub>	0.26 <sub>0.15</sub>
Proportions	0.39 <sub>0.09</sub>	0.32 <sub>0.09</sub>	0.45 <sub>0.11</sub>	0.17 <sub>0.14</sub>
Leg quality	0.06 <sub>0.09</sub>	0.15 <sub>0.09</sub>	0.03 <sub>0.10</sub>	0.01 <sub>0.14</sub>
Leg stance	-0.03 <sub>0.11</sub>	-0.07 <sub>0.11</sub>	-0.24 <sub>0.12</sub>	0.13 <sub>0.17</sub>
Hooves	0.52 <sub>0.09</sub>	0.45 <sub>0.09</sub>	0.39 <sub>0.11</sub>	0.41 <sub>0.16</sub>
Slow tölt	0.93 <sub>0.06</sub>	0.89 <sub>0.55</sub>	0.73 <sub>0.10</sub>	0.34 <sub>0.18</sub>
Walk	0.23 <sub>0.12</sub>	0.71 <sub>0.08</sub>	0.51 <sub>0.14</sub>	-0.10 <sub>0.18</sub>
Tölt	0.96 <sub>0.03</sub>	0.87 <sub>0.04</sub>	0.84 <sub>0.08</sub>	0.55 <sub>0.15</sub>
Trot	0.91 <sub>0.05</sub>	0.95 <sub>0.04</sub>	0.79 <sub>0.08</sub>	0.16 <sub>0.16</sub>
Pace (all records)	-0.14 <sub>0.07</sub>	-0.42 <sub>0.07</sub>	0.83 <sub>0.08</sub>	0.71 <sub>0.17</sub>
Pace (records ? 5.5)	0.38 <sub>0.11</sub>	0.12 <sub>0.11</sub>	0.86 <sub>0.08</sub>	0.83 <sub>0.15</sub>
Gallop	0.93 <sub>0.06</sub>	0.90 <sub>0.05</sub>	0.65 <sub>0.11</sub>	0.36 <sub>0.17</sub>
Spirit	0.94 <sub>0.04</sub>	0.87 <sub>0.04</sub>	0.79 <sub>0.09</sub>	0.43 <sub>0.15</sub>
General impression	0.88 <sub>0.05</sub>	0.75 <sub>0.06</sub>	0.83 <sub>0.08</sub>	0.68 <sub>0.20</sub>

## Genetic correlations between competition traits and breeding field-test traits (1)

Conformation	Tölt(comp)	4-gait	5-gait	PP1
Height of withers	0.15 <sub>0.09</sub>	0.15 <sub>0.09</sub>	0.14 <sub>0.10</sub>	0.38 <sub>0.15</sub>
Mane and tail	0.08 <sub>0.10</sub>	0.09 <sub>0.09</sub>	0.22 <sub>0.11</sub>	0.07 <sub>0.15</sub>
Head	0.28 <sub>0.09</sub>	0.23 <sub>0.10</sub>	0.24 <sub>0.11</sub>	-0.05 <sub>0.15</sub>
Neck, withers and shoulders	0.52 <sub>0.08</sub>	0.41 <sub>0.08</sub>	-0.05 <sub>0.18</sub>	0.29 <sub>0.14</sub>
Back and hindquarters	0.41 <sub>0.10</sub>	0.29 <sub>0.10</sub>	0.54 <sub>0.12</sub>	0.26 <sub>0.15</sub>
Proportions	0.39 <sub>0.09</sub>	0.32 <sub>0.09</sub>	0.45 <sub>0.11</sub>	0.17 <sub>0.14</sub>
Leg quality	0.06 <sub>0.09</sub>	0.15 <sub>0.09</sub>	0.03 <sub>0.10</sub>	0.01 <sub>0.14</sub>
Leg stance	-0.03 <sub>0.11</sub>	-0.07 <sub>0.11</sub>	-0.24 <sub>0.12</sub>	0.13 <sub>0.17</sub>
Hooves	0.52 <sub>0.09</sub>	0.45 <sub>0.09</sub>	0.39 <sub>0.11</sub>	0.41 <sub>0.16</sub>

## Genetic correlations between competition traits and breeding field-test traits(2)

Riding ability	Tölt(comp)	4-gait	5-gait	PP1
Slow tölt	0.93 <sub>0.06</sub>	0.89 <sub>0.55</sub>	0.73 <sub>0.10</sub>	0.34 <sub>0.18</sub>
Walk	0.23 <sub>0.12</sub>	0.71 <sub>0.08</sub>	0.51 <sub>0.14</sub>	-0.10 <sub>0.18</sub>
Tölt	0.96 <sub>0.03</sub>	0.87 <sub>0.04</sub>	0.84 <sub>0.08</sub>	0.55 <sub>0.15</sub>
Trot	0.91 <sub>0.05</sub>	0.95 <sub>0.04</sub>	0.79 <sub>0.08</sub>	0.16 <sub>0.16</sub>
Pace ≥ 5.5	0.38 <sub>0.11</sub>	0.12 <sub>0.11</sub>	0.86 <sub>0.08</sub>	0.83 <sub>0.15</sub>
Gallop	0.93 <sub>0.06</sub>	0.90 <sub>0.05</sub>	0.65 <sub>0.11</sub>	0.36 <sub>0.17</sub>
Spirit	0.94 <sub>0.04</sub>	0.87 <sub>0.04</sub>	0.79 <sub>0.09</sub>	0.43 <sub>0.15</sub>
General impression	0.88 <sub>0.05</sub>	0.75 <sub>0.06</sub>	0.83 <sub>0.08</sub>	0.68 <sub>0.20</sub>

# Genetic correlations between competition traits and breeding field-test traits

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- Moderately strong between
  - Most competition traits and
  - Neck, withers and shoulders; back and hindquarters; proportions; hooves
  
- Strong between
  - Most competition traits and
  - Slow tölt; walk; tölt; trot; pace; gallop; spirit; general impression

# Conclusions

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- 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
- A sufficient quantity of competition data needs to be made available in the future
  - data collection should be standardised
- Studies on the implementation of competition traits in the current method of genetic evaluation
  - Reliability
  - Genetic progress
  - Economic benefits?



# Conclusions

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The official breeding goal

*Multi-gaited riding horse with  
excellent temperament*



Applies equally to breeding horses and  
competition horses

# Thank you!

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# Glossary

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- Heritability
  - Of a trait is the proportion of the total variation (i.e. phenotypic) that is explained by the genetic variation (the additive genetic variation)
- Repeatability
  - The variation in measurements taken by a single individual on the same item and under the same conditions
- Skewness
  - A measure of the asymmetry of the probability distribution of a real-valued random variable
- Kurtosis
  - A measure of the “peakedness” of the probability distribution of a real-valued variable
- Correlation (Genetic; Residual; Permanent environmental)
  - Indicates the strength and direction of a linear relationship between two random variables
  - Genetic correlation; some genes have effect on various traits