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Selection for radiographic health of the limbs

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Background

- classical selection criteria in the Warmblood horse:
  - conformation
  - performance (mainly: riding sport)
- orthopedic diseases as main reason for losses and premature retirement of horses
  - regardless of kind of use
  - across riding disciplines
  - leisure and sport horses

Orthopedic diseases

- relevance
  - obvious clinical problems (lameness)
  - interference with maximum performance
  - findings indicating the risk of future clinical problems

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→
- diagnostic aspects
  - clinical findings (tissue swelling, heat, pain)
  - radiography
  - ultrasonography
  - ...

Orthopedic diseases and radiography

a) horses with musculoskeletal problems (lameness)

- important diagnostic tool
- identification of underlying diseases
  → choice of appropriate therapeutic measures

b) clinically sound horses

- prognostic use
- distinction between radiographic appearance within and beyond the range of physiological variation (international expert panels)
  → statements on presumptive risk of future orthopedic problems

→ pre-sale radiographic examinations

Orthopedic diseases and radiography

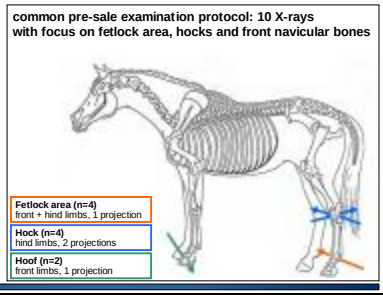
Pre-sale radiographic examinations

- motive:
  prognosis on future (long-term) usability of the horse
- occasion:
  - private sales
  - sales arranged by breeding societies
- relevance of outcome:
  reduction of market value in case of distinct radiographic findings

Orthopedic diseases and radiography

Pre-sale radiographic examinations

common pre-sale examination protocol: 10 X-rays with focus on fetlock area, hocks and front navicular bones



Prevalence of orthopedic diseases

- prevalence
  = frequency of occurrence in a study population
- basis of prevalence studies:
  - mostly clinically sound horses
  - radiographic findings (mainly limbs)

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→ role of orthopedic diseases:
  - not only in extensively used and/or old horses
  - high prevalences of certain diseases also in young horses

Prevalence of orthopedic diseases

Example:
Findings relating to osteochondrosis (OC) / osteochondrosis dissecans (OCD)

Reported prevalences of osseous / osteochondral fragments in equine fetlock (F) and hock (H) joints by breed and age

Horse population	Age	Sites of osseous fragments	% affected horses	Authors
German Warmblood	6 months to 3 years	F H	10.2 - 30.1 4.4 - 19.8	Herfst 1996; Leonhardt 1998; Heinz 1993; Müller 1994; Thoraen 1995; Kechner 1996; Wilkins et al. 1999; Kahler 2001; Wilke 2003
German Warmblood	3 to 8 years	F H	9.2 - 9.3 6.6 - 11.8	Müller 1992; Merz 1993; Winter et al. 1996
Dutch Warmblood	3 years	H	13.7	KWPN 1994
Swedish Warmblood	< 1 month to 3 years	H	26.0	Hoppe 1994a, b
Maremmano horses	2 to 3 years	F H	2.0 9.2	Pieramati et al. 2003
Norwegian trotters	< 1 month to 2 years	F H	11.0 14.3	Grøndahl 1991; 1992
Swedish trotters	< 1 month to 3 years	F H F and/or H	14.3 - 31.0 9.7 - 19.8 35.9	Hoppe 1994a,b; Carlsten et al. 1993; Sandgren et al. 1993
Danish trotters	< 1 month to 3 years	H	12.0	Ekman-Jagaard et al. 1980
American Draught horses	< 1 month to 3 years	F H	5.2 64.7	Riley et al. 1998

Measures against orthopedic diseases

- therapeutic measures
  - demanding (time, direct and indirect costs)
  - sometimes unsatisfactory results
    (incomplete recovery in terms of full performance capacity)

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→ search for prophylactic measures
  - regarding feeding and management
    (raising of the young horse, training practices, ...)
    → studies on nutrition, physiology, ...
  - regarding breeding
    (strategies accounting for orthopedic health traits)
    → population genetic studies

Genetics of orthopedic diseases

Example:
Results of population genetic studies (different countries, different estimation methods)

Reported heritability estimates for selected joint and bone diseases in the equine limbs

Populations and no. of investigated horses	Radiographic finding	Heritability estimate	Author
German Riding Horses (n = 2487 resp. 3995)	OCD	0.08 - 0.07	Weber et al. 1998
	Bone spavin	0.02 - 0.04	
	Pedetrochlosis	0.06	
German Riding Horses (mares; n = 401 resp. 456)	OCD	0.34 - 0.64	Wilms et al. 1998a
	Bone spavin	0.35 - 0.65	
	Pedetrochlosis	0.20 - 0.31	
German Riding Horses (foals; n = 164)	OCD	0.15 - 0.58	Wilms et al. 1998a
	Bone spavin	0.18 - 0.18	
	Pedetrochlosis	0.20 - 0.25	
Dutch Warmblood horses (mares; n = 590)	OCD (hock)	0.02 - 0.14	KWPN 1994
	Bone spavin	0.20 - 0.31	
	Navicular bone changes	0.30 - 0.32	
Maremmano horses (n = 350)	OCD	0.08 - 0.14	Piersanti et al. 2003
Norwegian trotters (n = 644)	OCD (fetlock)	0.62	Grøndahl and Dolvik 1993
	OCD (hock)	0.21	
Swedish Standardbred trotters (n = 760)	OCD (fetlock)	0.19 - 0.24	Philipsson et al. 1983
	OCD (hock)	0.17 - 0.27	
Danish trotters (n = 325)	OCD (hock)	0.26	Schougaard et al. 1987
Icelandic horses (n = 614)	Bone spavin	0.05 - 0.10	Björnsdóttir et al. 2006

Study aims

genetic analyses of radiographic health traits
in terms of
feasibility and efficiency of breeding measures
that simultaneously account for

- radiographic health of the limbs
- conformation
- performance

Study approach

- sample of uniformly examined young horses (radiographic examination records)
- combination with routinely collected conformation and performance data

realization:

- data and pedigree information made available by the Hanoverian Society
- analysis of data at the Institute for Animal Breeding and Genetics, University of Veterinary Medicine Hannover

Data sources

- **radiographic information**
  → young riding horses:
  data collected in connection with riding horse auctions
- **conformation information**
  → horses (mares) intended for breeding use:
  data from studbook inspections
- **performance information**
  → young riding horses:
  data collected in connection with riding horse auctions
  → horses (mares) intended for breeding use:
  results of mare performance tests

Data sources

Young riding horses

- regular horse sales arranged by the Hanoverian Society
- horses of similar age and training level
- selection procedure with standardized data collection (health, performance)

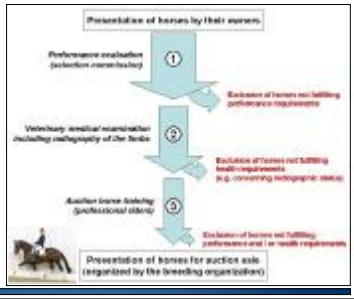
Data sources

Young riding horses

selection of auction horses as three-step-procedure:

a) performance records for 100% of presented horses (~ 750-1000 horses per year)

b) radiographic data for 70-75% of presented horses (~ 600-750 horses per year)



Data sources

Young riding horses

- regular horse sales arranged by the Hanoverian Society
- horses of similar age and training level
- selection procedure with standardized data collection (health, performance)

radiographic data available for this study:

- veterinary examination protocols from 1997-2004
- horses from birth years 1992-2001

Data sources

Horses (mares) intended for breeding use

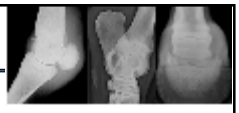
- conformation evaluation on the occasion of studbook evaluation (~ 2000-2300 mares per year)
- performance evaluation on the occasion of mare performance tests (~ 1000-1500 mares per year)
- horses of similar age and training level
- standardized data collection (conformation, performance)

Data basis for the genetic analyses

restriction to contemporaries of radiographically examined horses
→ 26,434 German Warmblood horses from birth years 1992-2001

No. of trait groups with records	RAD (n = 5,155)	CONF (n = 20,603)	PERF (n = 16,098)	No. of horses with records
1	X	-	-	2,169
	-	X	-	7,997
	-	-	X	2,100
2	X	X	-	170
	X	-	X	1,562
	-	X	X	11,182
3	X	X	X	1,254
1 - 3				26,434

Traits



Radiographic health traits (RAD)

findings previously determined to be

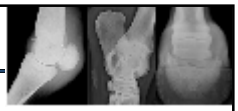
- quantitatively most important in the young riding horse
- relevantly influenced by genetic factors (heritabilities of 0.1-0.3)

Number and kind of traits: 4 binary traits

1) Osseous fragments in fetlock joints (1/0)
2) Osseous fragments in hock joints (1/0)
3) Deforming arthropathy in hock joints (1/0)
4) Distinct changes in the navicular bones (1/0)

binary traits: 1/ 0 coding with 1 = present and 0 = not present

Traits



Radiographic health traits (RAD)

Trait names used in this study	Trait names found in literature (synonyms or comparable but definitive)
Osseous fragments in fetlock joints	Fetlock joint osteochondrosis (Fetlock OCD); Fetlock joint osteochondrosis dissecans (Fetlock OCD)
Osseous fragments in hock joints	Hock joint osteochondrosis (Hock OCD); Tarsal joint osteochondrosis dissecans (Hock-OCD); Osteochondrosis (OC); osteochondrosis dissecans (OCD)
Deforming arthropathy in hock joints	Bone spavin
Distinct changes in the navicular bones	Pathological changes in the navicular bones; Navicular disease; Navicular bone

Traits

Conformation traits (CONF)

official records from studbook inspections for selected traits

Number and kind of traits: 3 continuous traits

1) Front limb conformation (score 1-10)
2) Hind limb conformation (score 1-10)
3) Withers height (measurement in cm)

continuous traits (linear traits): recorded on a scale with multiple levels

Traits

Performance traits (PERF)

records from auction horse inspections and
official results of mare performance tests for selected traits

Number and kind of traits: 5 continuous traits

1) Walk (score 1-10)
2) Trot (score 1-10)
3) Canter (score 1-10)
4) Rideability (score 1-10) [a]
5) Free jumping (score 1-10) [b]

[a] mean from judge and test rider scores (station tests) or judge score
[b] mean from scores for jumping ability and style

continuous traits (linear traits): recorded on a scale with multiple levels

Course of the genetic analyses

(1) multiple-trait estimation of genetic parameters
considering 12 traits (4 RAD, 3 CONF, 5 PERF)
→ heritabilities, genetic correlations

(2) genetic evaluation (prediction of breeding values)
→ use of breeding values
to compare alternative selection strategies
in terms of expected selection responses

Genetic parameters

Heritabilities (h^2)

heritability (range: 0.0 to 1.0)
extent to which trait variability (differences in trait expression) in a study population can be explained by genetic differences

Trait group	Trait	h^2
Radiographic findings (RAD)	Osseous fragments in fetlock joints	0.15
	Osseous fragments in hock joints	0.35
	Deforming arthropathy in hock joints	0.18
	Distinct changes in the navicular bones	0.23
Conformation (CONF)	Front limbs	0.10
	Hind limbs	0.11
	Withers height	0.50
Performance (PERF)	Walk	0.25
	Trot	0.38
	Canter	0.34
	Rideability	0.28
	Free jumping	0.39

Genetic parameters

Genetic correlations (r_g)

genetic correlation (range: -1.0 to 1.0)
extent to which traits are influenced by same genes
(pos. = same direction, neg. = opposite direction)

Trait	Osseous fragments in fetlock joints	Osseous fragments in hock joints	Deforming arthropathy in hock joints	Distinct changes in the navicular bones
Front limbs	0.28	-0.05	-0.28	-0.01
Hind limbs	0.29	0.01	-0.51	-0.16
Withers height	0.38	-0.59	-0.20	-0.12
Walk	0.00	-0.09	-0.08	-0.03
Trot	-0.04	-0.06	-0.10	0.01
Canter	0.09	-0.06	-0.25	-0.05
Rideability	0.04	0.01	-0.17	0.05
Free jumping	-0.10	0.00	-0.21	0.04

Prediction of breeding values

- breeding values as measures of the genetic value of an individual (relative to the whole population)
- standardization to **relative breeding values (RBV)** with same 'logical direction' for each of the 12 traits (higher RBV = more favorable)

Result of genetic evaluation	Meaning
RBV = 100	same genetic value as an average horse from the reference population
RBV > 100	higher genetic value (= more favorable combination of genes) than an average horse from the reference population
RBV < 100	lower genetic value (= less favorable combination of genes) than an average horse from the reference population

Expected selection responses (model)

1) 'selection'

- use of RBV to distinguish between sires
  → identification of sires with above-average RBV
- consideration of RBV for a single trait or traits from one trait group ("single-trait selection")
- consideration of RBV for traits from different trait groups ("multiple-trait selection")

Examples for single-trait selection:
Osseous fragments in fetlock joints
Rideability
RAD (= all radiographic findings)
Limbs (= front and hind limb conformation)
Gaits (= walk, trot and canter)

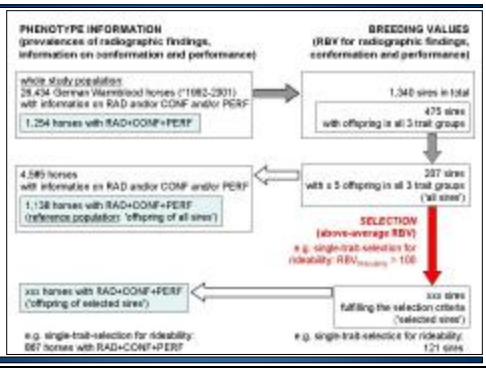
Examples for multiple-trait selection:
RAD + Free jumping
RAD + Limbs
RAD + Limbs + Gaits

Expected selection responses (model)

2) 'selection response'

- use of offspring phenotypes (radiographic findings, information on conformation and performance) to compare between groups of offspring
- definition of offspring groups by RBV of their sires

Expected selection responses (model)



Results

direct favorable selection responses
correlated favorable selection responses

Trait	Single-trait selection				
	RAD	Limbs	Gaits	Ride-ability	Free jumping
OFF	▒				
OFH	▒				
DAH	▒				
PCN	▒				
Front limbs		▒	▒	▒	
Hind limbs		▒	▒	▒	
Withers height					
Walk		▒	▒	▒	
Trot		▒	▒	▒	
Canter		▒	▒	▒	
Rideability		▒	▒	▒	
Free jumping					▒

Results

direct favorable selection responses
correlated favorable selection responses

Trait	Single-trait selection					Multiple-trait selection		
	RAD	Limbs	Gaits	Ride-ability	Free jumping	RAD + Limbs	RAD + PERF	RAD + Limbs + PERF
OFF	▒					▒	▒	▒
OFH	▒					▒	▒	▒
DAH	▒					▒	▒	▒
PCN	▒					▒	▒	▒
Front limbs		▒	▒	▒		▒		▒
Hind limbs		▒	▒	▒		▒		▒
Withers height								
Walk		▒	▒	▒		▒	▒	▒
Trot		▒	▒	▒		▒	▒	▒
Canter		▒	▒	▒		▒	▒	▒
Rideability		▒	▒	▒		▒	▒	▒
Free jumping					▒		▒	

Summary of results

- **radiographic health of the limbs**
  similar improvement (relative decrease of prevalences of radiographic findings) through
  'single-trait selection' on RAD and
  'multiple-trait selection' on RAD + Limbs + PERF
- **conformation and performance**
  similar improvement (relative increase of conformation and performance scores) through
  'single-trait selection' on Limbs or PERF and
  'multiple-trait selection' on RAD + Limbs + PERF

Conclusions

- feasibility of simultaneous selection for radiographic health traits, conformation traits and performance traits
- genetic correlations implying multiple-trait approach for genetic evaluation and selection to achieve maximum breeding progress for all traits of selection relevance in the Warmblood horse

general validity of these results needs to be proven

Thank you !