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Use of linear data for characterization and selection of sport horses with highest genetic potential

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Session 90
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Outline

- background:
  developments in sport horse breeding and their discussed side effects

- focus on sport horses with highest genetic potential for performance
  - comprehensive characterization
  - monitoring / risk analysis

- implications
  for sport horse breeding

Sport horse breeding

- success in riding sport as ultimate breeding goal
- specialization (dressage, show jumping) for maximal genetic gain
- framework for fast genetic progress
  - breeding programs and new tools for targeted decision support
  - high level of internationality (mostly open breeding policies)

challenges:

- early and reliable identification of horses with highest genetic potential for sport performance
- prevention of overemphasis of traits (side effects of 'extreme breeding')
- guide to balanced breeding decisions (responsible, sustainable breeding)

Study approach

- comprehensive characterization of top sport horses (from breeders' perspective)
  - sport performance in dressage and show-jumping
  - wide range of conformation traits
  - specific aspects of movement and jumping
- monitoring / risk analysis: systematic screening for patterns which may relate to detrimental long-term effects
- development of data-driven breeding advice with special attention paid to potentially unfavorable developments

Study population & sources of data

- active broodmares reflecting the two Oldenburg breeding populations specialized on dressage (D / OL) and jumping (J / OS)
- routine genetic evaluations → estimated breeding values (EBV)
  - EBV for sport traits from the national genetic evaluation for riding horses in Germany (FN)
    - rank-based → individual ranking among all starters
    - level-based → highest level achieved (lifetime summary)
    - ➢ dressage (DR, DL) and show-jumping (JR, JL)
  - phenotypes and EBV for linear conformation and performance traits from the genetic evaluation of the Oldenburg studbooks (OL+OS)

Linking of data

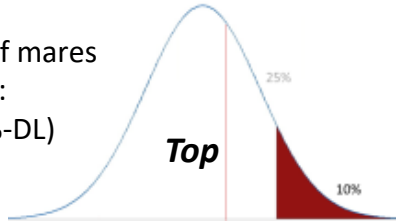
National genetic evaluation for riding horses

EBV for sport performance
in dressage (D) and show-jumping (J)

- sport data 1995-2022
  (national /FN, international/FEI)
- 6.1m starts of 279k horses for D,
  13.9m starts of 328k horses for J
- 2 traits per discipline:
  ranking (R) and highest level achieved (L)
- multiple-trait repeatability (R) and
  single trait (L) linear animal models

mares ranking among the 10% or 25% of mares with highest EBV for sport performance:

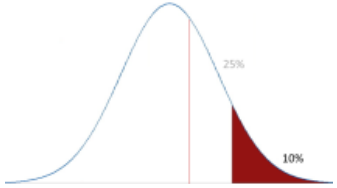
- **T10%-DR** (T25%-DR), **T10%-DL** (T25%-DL)
- **T10%-JR** (T25%-JR), **T10-JL** (T25%-JL)



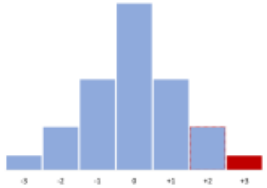
Genetic evaluation for linear conformation and performance traits (Oldenburg studbooks)

EBV for linear traits (**LIN-EBV**)

- OL+OS linear data 2012-2022
- 34,601 linear profiles of 31,936 horses (foals, adult horses) ⇨ progeny phenotypes for linear traits (**LIN-phen**)
- 46 traits: conformation,
  special remarks, gaits, jumping
- single- / multiple-trait repeatability
  linear animal models



'extreme EBV'



'extreme phenotype'

Data basis

- performance in sport competitions:
  10,298 mares with sport EBV (N_{OL} = 5,731, N_{OS} = 4,567)
- linear conformation, gaits, special remarks, jumping:
  12,172 mares with LIN-EBV (published: N_{OL} = 3,780, N_{OS} = 1,744)
- <u>statistical analyses:</u>
  - reference to relative breeding values (RBVs; mean 100, std 20)
  - minimum reliability of considered EBVs
    - sport EBV reliability ≥ 30% (2,873 - 5,187 mares; R > L) → percentiles
    - LIN-EBV based on own performance and/or at least 2 offspring
    - ➢ subsets of 1,084 (JL) to 2,737 (DR) mares

Statistical analyses

I. characterization of top performance mares (sport)
   - by referring to probabilities of extreme EBV for linear traits (top, bottom)
   - by evaluating probabilities of progeny with extreme phenotypes (+/-3)
   - ➢ higher probabilities in top mares than in the non-top mares?

II. monitoring of 'extreme breeding candidates' among the linear traits
   - by referring to EBV for sport and functionally important linear traits
   - by referring to progeny phenotypes of functionally important linear traits
   - ➢ higher probabilities in mares with extreme LIN-EBV than in the others?

- least square means (LSM)
  phenotypes: age groups Y (young), A (adult), consideration of age and pe

Results I Top10%-EBV performance / LIN-EBV

Trait group	Linear trait (probability of Top10% LIN-EBV or Bottom10% LIN-EBV)	DL (N=1,277)	DR (N=2,737)	JL (N=1,084)	JR (N=1,390)
walk	freedom of shoulders [short - long]	<0.001	<0.001	n.s.	n.s.
	reach of hind limbs (overstepping) [inactive (short) - active (long)]	<0.001	<0.001	n.s.	n.s.
trot	freedom of shoulders [short - long]	<0.001	<0.001	n.s.	n.s.
	mechanics of front limbs [straight forelimb - much knee action]	<0.001	<0.001	n.s.	n.s.
	impulsion [weak - powerful]	<0.001	<0.001	n.s.	n.s.
	thrust (hind limb activity) [inactive, sluggish - active, energetic]	<0.001	<0.001	n.s.	n.s.
	carrying power [pushing - carrying]	<0.001	<0.001	n.s.	n.s.
	suppleness [tense - supple]	0.002	<0.001	n.s.	n.s.
canter	freedom of shoulders [short - long]	<0.001	<0.001	n.s.	n.s.
	mechanics of front limbs [straight forelimb - much knee action]	<0.001	<0.001	n.s.	n.s.
	direction of movement [downhill - uphill]	<0.001	<0.001	n.s.	n.s.
	Thrust (hind limb activity) [inactive, sluggish - active, energetic]	<0.001	<0.001	n.s.	n.s.
jumping	rhythm [not fluent - fluent]			<0.001	<0.001
	take-off power [weak - powerful]			<0.001	<0.001
	reflexes [slow, inflexible - quick, flexible]			n.s.	<0.001
	attention [inattentive - attentive]			n.s.	<0.001
	overview [little - much]			<0.001	<0.001
	ability [little scope - much scope]			<0.001	<0.001
	foreleg angulation [straight - angulated]			n.s.	0.066
	back technique (bascule) [hollow back - rounded back]			0.054	n.s.
	hind leg technique (haunches) [tight (under the body) - long hind leg]			n.s.	n.s.

- patterns reflecting genetic correlations
- r_g ↑→ probability of co-occurrence of 'extreme' EBV ↑

D vs. J ✓

Results II Top10%-EBV performance / LIN-EBV

Trait group	Linear trait (probability of Top10% or Bottom10% LIN-EBV)	DL (N=1,277)	DR (N=2,737)	JL (N=1,084)	JR (N=1,390)
type	Breed type [plain - true to type]	0.004	<0.001	n.s.	n.s.
	Gender expression [weak - strong]	0.016	<0.001	n.s.	0.086
	Head shape [coarse - fine]	n.s.	<0.001	n.s.	0.084
	Eye size [small - large]	0.003	<0.001	n.s.	n.s.
format	Frame [small-framed - large-framed]	0.076	0.003	0.017	n.s.
	Caliber [light - heavy]	n.s.	n.s.	n.s.	0.041
	[light - heavy]	0.060	<0.001	n.s.	n.s.
	Length of legs [short-legged - long-legged]	<0.001	<0.001	n.s.	n.s.
neck	Set of neck [low - high]	0.009	n.s.	n.s.	n.s.
	Muscling area of neck [ewe-necked - top line dom. neck]	n.s.	n.s.	n.s.	n.s.
	Shape of neck [straight - arched]	n.s.	n.s.	n.s.	n.s.
	Length of withers [short - long]	0.047	0.010	n.s.	n.s.
	Height of withers [flat - high]	n.s.	n.s.	n.s.	n.s.
back	Length of back [short - long]	n.s.	0.001	0.022	n.s.
	[short - long]	n.s.	<0.001	n.s.	n.s.
	Line (strength) of back [dipped (weak) - roached]	n.s.	<0.001	n.s.	n.s.
	Line (strength) of loins [dipped (weak) - roached]	n.s.	n.s.	n.s.	n.s.
	Angle (inclination) of croup [flat (level) - sloping]	0.023	n.s.	n.s.	n.s.
	Set of tail [low - high]	n.s.	n.s.	n.s.	n.s.
	[low - high]	n.s.	<0.001	n.s.	n.s.

traits of functional relevance and with intermediate optima requiring special attention

D >> J ✓

- patterns reflecting genetic correlations
- r_g ↑→ probability of co-occurrence of 'extreme' EBV ↑

Results III Top10%-EBV performance / LIN-EBV

Trait group	Linear trait (probability of Top10% or Bottom10% LIN-EBV)	DL (N=1,277)	DR (N=2,737)	JL (N=1,084)	JR (N=1,390)
limbs	Length of FL pastern [short - long]	<0.001	n.s.	n.s.	0.043
	Stance of FL pastern [upright - sloping (weak)]	n.s.	n.s.	0.002	n.s.
	Stance of HL pastern [upright - weak]	n.s.	n.s.	n.s.	0.045
	Hock angulation [straight - angulated]	0.019	n.s.	n.s.	n.s.
	Size of joints [small - big]	0.087	n.s.	n.s.	0.031
	[small - big]	<0.001	<0.001	n.s.	n.s.
	Toe stance of forelegs [toe-in - toe-out]	n.s.	n.s.	n.s.	0.019
	[toe-in - toe-out]	n.s.	n.s.	n.s.	0.081
special remark	Tail tone [un-toned - over-toned]	0.078	0.014	<0.001	0.083
	[un-toned - over-toned]	n.s.	n.s.	n.s.	n.s.

traits of functional relevance and with intermediate optima requiring special attention

D >> J ✓

- patterns reflecting genetic correlations
- r_g ↑→ probability of co-occurrence of 'extreme' EBV ↑

Results IV Top10%-EBV performance / LIN-phen

Trait group	Linear trait (probability of linear phenotype of +3 or -3)	DL (N_Y=2,800, N_A=1,125)		DR (N_Y=5,128, N_A=1,744)		JL (N_Y=1,944, N_A=508)		JR (N_Y=2,385, N_A=512)	
		Y	A	Y	A	Y	A	Y	A
format	Frame [small-framed - large-framed]	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Caliber [light - heavy]	n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.
	Length of legs [short-legged - long-legged]	n.s.	n.s.	n.s.	+	n.s.	n.s.	n.s.	n.s.
neck	Set of neck [low - high]	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
back	Length of back [short - long]	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Angle (inclination) of croup [flat (level) - sloping]	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Set of tail [low - high]	n.s.	n.s.	n.s.	**	n.s.	n.s.	n.s.	n.s.
limbs	Length of FL pastern [short - long]	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Stance of FL pastern [upright - sloping (weak)]	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Stance of HL pastern [upright - weak]	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Hock angulation [straight - angulated]	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Size of joints [small - big]	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.
	Toe stance of forelegs [toe-in - toe-out]	n.s.	n.s.	n.s.	+	n.s.	n.s.	n.s.	n.s.
	[toe-in - toe-out]	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	**
special remark	Tail tone [un-toned - over-toned]	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.
	[un-toned - over-toned]	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.	n.s.

traits of functional relevance and with intermediate optima requiring special attention

- rarely found extremes among progeny phenotypes of the analyzed groups of mares
- no indications of strong shifts towards extreme linear trait expressions (phenotypes) when focusing on top sport performance

✓ **TROT Thrust (hind limb activity)** [inactive, sluggish - active, energetic]

Top10%-EBV (DL, DR)	LSM LIN-phen +3 in %			
	DL-Y	DL-A	DR-Y	DR-A
0 (no)	0.98	1.69	1.19	2.03
1 (yes)	2.41	3.32	2.88	5.91

(!) **Caliber** [light - heavy]

Top10%-EBV (DL, DR)	LSM LIN-phen -3 in %			
	DL-Y	DL-A	DR-Y	DR-A
0 (no)	0.09	0.09	0.08	0.06
1 (yes)	0.00	0.59	0.19	0.64

Results V Top10%- or Bot10%-LIN-EBV / LIN-phen

Trait group	Linear trait (probability of Top10% or Bottom10% LIN-EBV and of linear phenotype of +3 or -3)	LIN-EBV	LIN-phen	
			Y	A
format	Frame [small-framed - large-framed]	n.s.	n.s.	n.s.
	Length of legs [short-legged - long-legged]	<0.001	n.s.	n.s.
neck	Set of neck [low - high]	0.083	n.s.	n.s.
back	Length of back [short - long]	n.s.	n.s.	n.s.
	Angle (inclination) of croup [flat (level) - sloping]	0.018	n.s.	n.s.
	Set of tail [low - high]	<0.001	n.s.	n.s.
limbs	Length of FL pastern [short - long]	<0.001	**	**
	Stance of FL pastern [upright - sloping (weak)]	n.s.	n.s.	n.s.
	Stance of HL pastern [upright - weak]	n.s.	n.s.	n.s.
	Hock angulation [straight - angulated]	n.s.	n.s.	n.s.
	Size of joints [small - big]	<0.001	n.s.	+
	Toe stance of forelegs [toe-in - toe-out]	0.034	n.s.	n.s.
	[toe-in - toe-out]	n.s.	n.s.	n.s.
special remark	Tail tone [un-toned - over-toned]	0.007	n.s.	n.s.
	[un-toned - over-toned]	<0.001	n.s.	n.s.

traits of functional relevance and with intermediate optima requiring special attention

- genetic correlations between linear traits to be considered
- possible (unfavorable) side-effects of strong focus on particular linear trait aspects to be monitored

✓ **Sport performance - dressage**

Bot10%-LIN-EBV Caliber	LSM Top10% EBV in %	
	DL	DR
0 (no)	10.4	12.7
1 (yes)	15.8	23.1

! **Length of FL pastern** [short - long]

Bot10%-LIN-EBV Caliber	LSM Top10% LIN-EBV or LIN-phen +3 in %		
	LIN-EBV	LIN-phen Y	LIN-phen A
0 (no)	12.3	0.00	0.00
1 (yes)	29.3	0.31	0.73

Summary & conclusions

- patterns of 'extreme' breeding values ≈ genetic correlation patterns
- significant genetic progress in sport performance and corresponding indicator traits, i.e. performance related linear traits,
  but no indications of alarming developments on phenotypic level
- comprehensive linear data allowing to illustrate risks of
  over-emphasis of single aspects ('candidates for extreme breeding')

Implications

- breeding values for linear traits as valuable tools for targeted improvements and sustainable progress in sport horse breeding
  - performance
  - functionality
- genetic correlations implying correlated selection responses
  - use of 'high-resolution phenotyping' for systematic monitoring to recognize and counteract possible tendencies towards over-emphasis of certain aspects which may harm long-term functional integrity
  - responsibility of breeders not to lose sight of the 'overall picture' and to make balanced breeding decisions

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Further information on
linear profiling and related activities:

Equine Phenotypes

TAKE HOME

- use of 'high-resolution phenotyping' for systematic monitoring to recognize and counteract possible tendencies towards over-emphasis of certain aspects which may harm long-term functional integrity
- responsibility of breeders not to lose sight of the 'overall picture' and to make balanced breeding decisions

Thank you !