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**The correlation between inbreeding and
performance
in the Hanoverian Sport Horse.**

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Abstract

The aim of this thesis was to examine the relationship between inbreeding and performance in the Hanoverian Sport Horse.

A total of 84,724 Hanoverian horses born between the years 1990 and 2009 were used for the study, of which 78,907 had their own performance records. Pedigree records were traced back as far as possible, with a maximum of 37 generations used. There was 100% completeness of pedigree up to the grandparent generation for all horses. The majority of horses (80%) had completeness of pedigree past the sixth generation.

Inbreeding was calculated using two methods; the Meuwissen method and the van Raden Method. Both methods gave identical results (100% fit). As a quantitative measure of performance, the Integrated Estimated Breeding Value (iEBV), using both breed and competition results was used. The evaluation was carried out using the BLUP (Best Linear Unbiased Prediction) Multitrait Repeatability Animal Model. Two different GLM were run with the inbreeding coefficient (IBC) modelled as either a continuous variable or as a fixed class of five differing levels of inbreeding ($IBC=0.00$; $0 < IBC \leq 0.01$; $0.01 < IBC \leq 0.02$; $0.02 < IBC \leq 0.05$; $0.05 < IBC$). Age and Sex were included as fixed effects within the model.

All subgroups in both dressage and jumping data, with either fixed effect or linear covariate for the IBC, generated a similar result. Due to the large sample size there was a significant ($p < 0.001$) relationship between inbreeding (IBC) and performance (iEBV). In dressage horses there was a significant positive relationship in all categories while in jumping horses there was a significant negative relationship in all categories. However, the effect of inbreeding on iEBV explained only $\pm 1\%$ of the variance in the models. The models were simultaneously adjusted for the bias of the confounding factor of sex which also accounted for $\pm 1\%$ of the variance. The majority of variance in iEBV is due to the year cohort effect which accounts for $\pm 95\%$. The low level of inbreeding ($\pm 1.5\%$) and lack of biological effect on iEBV indicate that inbreeding is not a problem in the Hanoverian horse.

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List of abbreviations and terms

| | |
|-----------------------|---|
| APB | (Aufbauprüfung) Sport events – show jumping and dressage of Young Horses' competitions, |
| ATSE | Accumulated, transformed and standardized earnings |
| BLUP | Best Linear Unbiased Predictor Multi-trait–Repeatability–Animal Model |
| BYEAR _k | fixed effect of birth year class (k=1-10; 1990-1991, 1992-1993, ..., 2008- 2009) |
| CPT | Central performance tests |
| DF | Degrees of freedom |
| DKB-Bundeschampionate | The German Championships of Young German Horses and Ponies |
| Dressage horses | Refers to the dressage data of the relevant horse subgroup |
| DWB | Dutch Warmblood horse |
| eijkl | Random residual |
| F | Coefficient of inbreeding as defined by Sewall Wright |
| F _A | Inbreeding Coefficient of the common ancestor |
| F _x | Inbreeding Coefficient of individual horse |
| FE | Fixed effect |
| FEI | Federation Equestre Internationale |
| FN | Fédération Equestre Nationale (Germany) |
| GLM | General Linear Model |
| H ² | Heritability |
| HLP | (Hengstleistungsprüfung) Stallion performance test. |
| i | Intensity of selection of genetic gain |

| | |
|-------------------|---|
| IBC | Inbreeding coefficient |
| IBCi | Inbreeding coefficient of horse _i |
| IBCC _i | Fixed effect of inbreeding coefficient class (i=1-5; IBC=0.00, 0.00 < IBC ≤ 0.01, 0.01 < IBC ≤ 0.02, 0.02 < IBC ≤ 0.05, IBC > 0.05) |
| iEBV | Integrated Estimated Breeding Value |
| IGE | Integrated Genetic Evaluation |
| IHB | Irish Horse Board |
| Jumping Horses | Refers to the jumping data of the relevant horse subgroup |
| KWPN | Royal Dutch Sport Horse |
| LC | linear covariate |
| <i>Meuw.f</i> | The Meuwissen method for computation of inbreeding coefficients |
| MPT | iEBV for mare performance test |
| MPTD | iEBV for dressage in mare performance test |
| MPTJ | iEBV for jumping in mare performance test |
| N | Number of horses in relevant subgroup |
| n ₁ | Number of generations from the sire to the common ancestor |
| n ₂ | Number of generations from the dam to the common ancestor |
| p | P-value |
| Pr | “The probability of” |
| PEDIG | Fortran 77 software package used for computation of inbreeding coefficients |
| r | Accuracy of selection of genetic gain |
| R ² | R-squared |
| RF | Rasmussen Factor |
| r _g | Genetic Correlation |
| SEX _j | Fixed effect of sex |

| | |
|-----------------|---|
| S.D. | Standard Deviation |
| SF | Selle Français horse |
| SPT | iEBV for stallion performance test. |
| SPTD | iEBV for dressage in stallion performance test. |
| SPTJ | iEBV for jumping in stallion performance test. |
| SS | Sum of Squares |
| SWB | Swedish Warmblood horse |
| T | Generation interval |
| TC | iEBV for Tournament competitions |
| TCD | iEBV for tournament competitions dressage |
| TCJ | iEBV for Tournament competitions jumping |
| TI | Total Index |
| TID | Total Index Dressage |
| TIJ | Total Index Jumping |
| TIMEFORM | Relates to Timeform Publications and is a publishing company in Halifax, West Yorkshire, England as used by the racing industry to produce information and statistics on individual racehorses. |
| TORIS | Turnier ORganisations und Informations System |
| TSP | (Turniersportprüfung) Sport events - show jumping and dressage competitions. |
| V _P | Phenotypic variation |
| V _G | Variation in genetic values |
| VA | (Veranlagungsprüfung) ability test of young stallions, |
| <i>vanrad.f</i> | The van Raden method for the computation of inbreeding coefficients |
| YC | iEBV for Young Horse competitions |

| | |
|-------|---|
| YCD | iEBV for Young Horse competitions dressage |
| YCJ | iEBV for Young Horse competitions jumping |
| yijkl | Breeding value (iEBV) |
| ZSP | (Zuchtstutenprüfung) Own performance test of mares, |
| μ | Model constant |

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List of Equations

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Heritability

$$H^2 = V_G/V_P$$

H = Heritability

V_P = phenotypic variation

V_G = Genotypic variation

Equation 2:

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coefficient of inbreeding (F) defined by Sewall Wright in the early 1920s

$$F_X = \sum \left[\left(\frac{1}{2} \right)^{n_1 + n_2 + 1} (1 + F_A) \right]$$

F_X = Inbreeding Coefficient of individual horse

F_A = Inbreeding Coefficient of the common ancestor

n_1 = Number of generations from the sire to the common ancestor

n_2 = Number of generations from the dam to the common ancestor

List of Models

Model 1:

45

$$y_{ijkl} = \mu + b \text{IBC}_i + \text{SEX}_j + \text{BYEAR}_k + e_{ijkl}$$

y_{ijkl} = breeding value (iEBV)

μ = model constant

IBC_i = inbreeding coefficient of horse_i

SEX_j = fixed effect of sex

BYEAR_k = fixed effect of birth year class ($k=1-10$; 1990-1991, 1992-1993, ..., 2008-2009)

e_{ijkl} = random residual

Model 2:

45

$$y_{ijkl} = \mu + \text{IBCC}_i + \text{SEX}_j + \text{BYEAR}_k + e_{ijkl}$$

y_{ijkl} = breeding value (iEBV)

μ = model constant

IBCC_i = fixed effect of inbreeding coefficient class ($i=1-5$; $\text{IBC}=0.00$, $0.00 < \text{IBC} \leq 0.01$, $0.01 < \text{IBC} \leq 0.02$, $0.02 < \text{IBC} \leq 0.05$, $\text{IBC} > 0.05$)

SEX_j = fixed effect of sex ($j=1-2$; stallions, mares)

BYEAR_k = fixed effect of birth year class ($k=1-10$; 1990-1991, 1992-1993, ..., 2008-2009)

e_{ijkl} = random residual