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# Selection strategies for radiographic findings in German Warmblood horses

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## Summary

The results of a standardized radiological examination of 5,928 Hanoverian Warmblood horses selected for sale at auction were analyzed for their genetic background. They were further used to predict relative breeding values (RBV) for the most prevalent radiographic findings, i.e., osseous fragments in fetlock (OFF; 20.8%) and hock joints (OFH; 9.1%), deforming arthropathy in hock joints (DAH; 11.7%) and pathologic changes in navicular bones (PCN; 24.7%). A total index radiographic findings (TIR) was derived from these RBV. The TIR was combined with the officially published total indices for dressage (TID) and jumping (TIJ) to develop selection strategies that account for orthopaedic health traits and for performance criteria.

Genetic parameters were estimated with REML under both linear animal and linear sire models. After transformation to the underling liability scale the heritability estimates for radiographic findings were in the range of $h^2$ = 0.14-0.46. They were correlated additive genetically with $r_g$ = -0.34 to 0.24. If selection of sires was half-and-half based on performance criteria and radiological state, the percentages of above-average sires were almost the same as in the case of exclusively performance-based selection. However, all total indices significantly increased in the selected sires, and the prevalences of radiographic findings decreased in their offspring. Therefore, the prediction of breeding values for radiographic findings can be recommended to improve the horses' radiological state.
**Keywords:** horse; radiographic findings; breeding values; selection

## Introduction

Diseases of the equine locomotory system interfere with the horses' use and affect all sections of horse industry. In many modern horse breeds the approval of breeding animals depends not only on type traits and performance criteria such as quality of gaits and jumping

ability, but also on their clinical and radiological health status. The hereditary nature of particular diseases of the equine skeleton has been documented in several studies (e.g., Grøndahl and Dolvik 1993, Philipsson et al. 1993, KWPN 1994, Winter et al. 1996, Willms et al. 1999, Bjørnsdottir et al. 2000, Pieramati et al. 2003). Therefore, the most efficient way to lower the prevalences of these diseases will be the implementation of specific breeding programs that account for radiographic findings. Nevertheless, the prediction of breeding values in the horse is still exclusively based on type and performance data.

For this reason, the results of an extensive study on radiographic findings in the limbs of young Warmblood riding horses were used to substantiate the role of genetics in the development of radiographic findings and to predict breeding values for those orthopedic diseases that were found to be of major importance. On this basis, selection schemes were tested which concurrently account for radiographic findings and for performance traits.

## Material and methods

The results of a standardized radiographic examination of a total of 5,928 Hanoverian Warmblood horses (probands) were used for this investigation. They were all selected for sale at auction as riding horses in 1991-2003 by the Society of Hanoverian Warmblood Breeders (Verband hannoverscher Warmblutzüchter e.V., VHW) in Verden on the Aller, Germany. 5,680 of the probands were actually offered for sale (auction horses; mean age of 4.0 ± 0.8 years; 3,601 male and 2079 female horses), whilst 248 of the probands were selected, but pulled out of the auction.

The four most prevalent radiographic findings chosen for further analyses were (1) osseous fragments in fetlock joints (OFF), (2) osseous fragments in hock joints (OFH), (3) deforming arthropathy in hock joints (DAH), and (4) pathologic changes in navicular bones (PCN), having occurred in 20.8%, 9.1%, 11.7%, and 24.7% of the probands, respectively.

Pedigree data were taken from a unified animal ownership database (Vereinigte Informationssysteme Tierhaltung w.V., VIT) in Verden on the Aller, Germany. The 5,928 probands were sired by 614 different stallions contributing up to 211 horses selected for sale at auction in 1991-2003. For all the genetic analyses, pedigree informations on four generations were considered.

Genetic parameters were estimated multivariately using Residual Maximum Likelihood (REML) with VCE4, Version 4.2.5 (Variance Component Estimation; Groeneveld, 1998) under both, linear animal models (LAM) and linear sire models (LSM). The applied models

were developed in the course of multiple analyses of variance using the procedure GENMOD of the Statistical Analysis System (SAS), version 8.2 (SAS Institute, Cary, NC, 2003).

(1) $y_{ijko} = \mu + Auction_i + Sex_j + Age_k + a_o\ (s_o) + e_{ijko}$

(2) $y_{ijklmno} = \mu + Auction_i + Sex_j + Age_k + Suit_l + RegB_m + RegE_n + a_o\ (s_o) + e_{ijklmno}$

(3) $y_{ijlo} = \mu + Auction_i + Sex_j + Suit_l + a_o\ (s_o) + e_{ijlo}$

(4) $y_{ijko} = \mu + Auction_i + Sex_j + Age_k + a_o\ (s_o) + e_{ijko}$

with $y_{ijklmno}$ = radiographic finding of the proband, $\mu$ = model constant, $Auction_i$ = fixed effect of the date of auction (i = 1-67), $Sex_j$ = fixed effect of the sex (j = 1-2), $Age_k$ = fixed effect of the age group (k = 1-3), $Suit_l$ = fixed effect of the anticipated suitability (l = 1-3), $RegB_m$ = fixed effect of the region of breeder (m = 1-3), $RegE_n$ = fixed effect of the region of exhibitor (n = 1-3), $a_o\ (s_o)$ = random additive genetic effect of the o-th animal (sire), and $e_{ijklmno}$ = residual error.

Heritabilities ($h^2$), additive genetic ($r_g$) and residual correlations ($r_e$) were calculated from the estimates of the additive genetic ($\sigma^2_a$, $cov_a$) and residual (co)variances ($\sigma^2_e$, $cov_e$). The heritability estimates and the estimated residual correlations of the LAM and LSM analyses were transformed onto the liability scale according to Dempster and Lerner (1950) and Vinson et al. (1976). The (co)variance matrices were further utilized to predict breeding values for the investigated radiographic findings for all the 23,662 horses appearing in the last four generations of the probands' pedigree. The calculations were done using PEST (Groeneveld, 1990) and applying the same multivariate linear animal models (LAM) as for the estimation of genetic parameters. The breeding values were standardized on a relative scale with a mean of 100 and a standard deviation of 20. The 1,981 probands born in 1987-1991 were used as the reference population for the standardization. Transformation was done that way that larger relative breeding values (RBV) will mean that the horses are less likely to transmit a predisposition for a particular radiological finding. Accordingly, horses with lower RBV are considered to transmit a higher disposition for particular radiological findings. The RBV were further used to derive a total index radiographic findings (TIR) as TIR = ($RBV_{OFF}$ + $RBV_{OFH}$ + $RBV_{DAH}$ + $RBV_{PCN}$) / 4.

358 of the 368 sires with at least three offspring among our probands were listed in the Annual for Breeding and Sports 2002 (Jahrbuch Zucht und Sport, 2002), published by the Fédération Equestre Nationale (FN, Deutsche Reiterliche Vereinigung e.V.) in Warendorf, Germany. For these 358 stallions the TIR and the RBV for radiographic findings were compared with the official performance based relative breeding values (TID, TIJ) using the

Pearson correlation coefficients of the procedure CORR of the Statistical Analysis System (SAS), version 8.2 (SAS Institute, Cary, NC, 2003).

The total indices were further used to develop selection schemes that gave varying weight to TIR, TID and/or TIJ. In order to assess the expected response to selection, the lots of above-average sires were compared with the whole group of the probands' sires (n = 358) by their mean relative breeding values (TID, TIJ, TIR; $RBV_{OFF}$, $RBV_{OFH}$, $RBV_{DAH}$ and $RBV_{PCN}$) and by the prevalences of the OFF, OFH, DAH and PCN in their offspring.

## Results

Genetic parameters estimated for the prevalences of OFF, OFH, DAH and PCN are shown in Table 1. In general, there were only minor differences between LAM and LSM estimates. The heritability estimates were in the range of $h^2$ = 0.15-0.46, with the lowest and highest estimates obtained for OFF ($h^2$ = 0.15) and PCN ($h^2$ = 0.41-0.46), respectively. Slightly to moderately negative additive genetic correlations were estimated between OFF and OFH ($r_g$ = -0.19 to -0.34), and between OFH and DAH ($r_g$ = -0.12 to -0.14). OFF were genetically correlated moderately positive with DAH ($r_g$ = 0.23-0.39). No relevant additive genetic correlations were estimated between PCN and OFF, OFH and DAH ($r_g$ = -0.11 to 0.04).

TABLE 1: Heritability estimates (transformed estimate on the diagonal), additive genetic correlations (above the diagonal), and residual correlations (transformed estimate below the diagonal) with their standard errors for the prevalences of osseous fragments in fetlock (OFF) and hock joints (OFH), of deforming arthropathy in hock joints (DAH), and of pathologic changes in navicular bones (PCN), using linear animal models (LAM; first line) and linear sire models (LSM; second line)

| Radiographic finding | OFF | OFH | DAH | PCN |
|---|---|---|---|---|
| OFF | **0.150 ± 0.027**<br>**0.145 ± 0.030** | -0.191 ± 0.123<br>-0.338 ± 0.140 | 0.226 ± 0.132<br>0.390 ± 0.146 | -0.069 ± 0.102<br>-0.109 ± 0.120 |
| OFH | 0.022 ± 0.034<br>-0.007 ± 0.024 | **0.323 ± 0.051**<br>**0.314 ± 0.060** | -0.137 ± 0.125<br>-0.116 ± 0.152 | -0.086 ± 0.089<br>-0.086 ± 0.105 |
| DAH | -0.051 ± 0.031<br>-0.020 ± 0.022 | -0.020 ± 0.039<br>-0.051 ± 0.028 | **0.215 ± 0.042**<br>**0.199 ± 0.052** | -0.011 ± 0.097<br>0.036 ± 0.116 |
| PCN | -0.017 ± 0.030<br>-0.026 ± 0.019 | 0.073 ± 0.038<br>0.042 ± 0.024 | 0.097 ± 0.033<br>0.079 ± 0.022 | **0.406 ± 0.039**<br>**0.463 ± 0.051** |

Correlations between the officially published breeding values and the RBV predicted for radiographic findings are shown in Table 2. Neither DAH nor OFF or OFH were significantly correlated with TID or TIJ (r = -0.03 to 0.08). However, slightly negative correlations were determined between PCN and TID (r = -0.10), and between PCN and TIJ (r = -0.16).

TABLE 2: Correlations between the official relative breeding values for dressage (total index dressage, TID) and show-jumping (total index jumping, TIJ) and the relative breeding values (RBV) predicted for osseous fragments in fetlock (OFF) and hock joints (OFH), deforming arthropathy in hock joints (DAH) and pathologic changes in navicular bones (PCN)

| | TID | TIJ | $RBV_{OFF}$ | $RBV_{OFH}$ | $RBV_{DAH}$ | $RBV_{PCN}$ |
|---|---|---|---|---|---|---|
| TID | 1.000 | -0.063 | 0.079 | -0.006 | 0.048 | -0.095 $^{+}$ |
| TIJ | | 1.000 | -0.026 | 0.030 | -0.025 | -0.160 $^{**}$ |
| $RBV_{OFF}$ | | | 1.000 | -0.228 $^{***}$ | 0.175 $^{***}$ | -0.060 |
| $RBV_{OFH}$ | | | | 1.000 | -0.242 $^{***}$ | -0.019 |
| $RBV_{DAH}$ | | | | | 1.000 | -0.052 |
| $RBV_{PCN}$ | | | | | | 1.000 |

Levels of significance: *** : $P < 0.001$; ** : $P < 0.01$; * : $P < 0.05$; + : $P < 0.10$

If selection of sires was solely based on performance criteria (i.e., the transmission of dressage and/or jumping ability), between 40 and 65% of the probands' sires were selected (Table 3). These percentages remained almost unchanged when the selection decision was half-and-half based on performance criteria and the radiological state (i.e., the disposition to show particular radiological findings). However, in this way all considered total indices could be increased and the prevalences of all investigated radiographic findings could be lowered.

TABLE 3: Percentages of selected sires (n = 358) and expected responses to selection (relative changes of the mean total indices for dressage (TID), jumping (TIJ) and radiographic findings (TIR) in the selected sires, and of the prevalences of osseous fragments in fetlock (OFF) and hock joints (OFH), deforming arthropathy in hock joints (DAH) and pathologic changes in navicular bones (PCN) in the probands that descended from selected sires) when selecting for performance or for performance and radiographic findings

| | Selection for performance (100%) | | Selection for performance (50%) and for radiographic findings (50%) | |
|---|---|---|---|---|
| | Percentage of selected sires | Expected response to selection | Percentage of selected sires | Expected response to selection |
| Dressage | 64.5% | TID + 9.1% | 64.0% | TID + 8.2% |
| | | TIR + 1.0% | | TIR + 4.0% |
| | | OFF + 2.9% | | OFF – 2.4% |
| | | OFH – 1.1% | | OFH – 6.6% |
| | | DAH +/– 0% | | DAH – 5.1% |
| | | OFH – 4.5% | | OFH – 9.3% |
| Show-jumping | 39.7% | TIJ + 19.4% | 45.5% | TIJ + 15.3% |
| | | TIR + 1.0% | | TIR + 4.0% |
| | | OFF + 2.4% | | OFF – 4.8% |
| | | OFH – 1.1% | | OFH – 9.9% |
| | | DAH +/– 0% | | DAH – 10.3% |
| | | OFH – 1.2% | | OFH – 8.9% |
| Dressage and show-jumping | 56.4% | TID + 7.3% | 55.3% | TID + 6.4% |
| | | TIJ + 7.1% | | TIJ + 6.1% |
| | | TIR + 1.0% | | TIR + 5.1% |
| | | OFF + 3.8% | | OFF – 4.8% |
| | | OFH – 5.5% | | OFH – 9.9% |
| | | DAH – 3.4% | | DAH – 10.3% |
| | | OFH – 3.2% | | OFH – 7.3% |

## Conclusions

The heritable character of the most important radiographic findings in the limbs of young Warmblood riding horses, i.e. of osseous fragments in fetlock and hock joints, deforming arthropathy in hock joints and pathologic changes in navicular bones, has been substantiated. The results of this study indicate that is it possible to develop selection strategies that simultaneously account for orthopaedic health traits and for performance traits. Therefore, the prediction of breeding values for radiographic findings can be recommended as a long-term measure to improve the radiological state of the Warmblood horse population.

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