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Genetic and environmental factors influencing gestation length and parturition conception interval in Hanoverian warmblood

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ABSTRACT

The present study has the objectives to analyse effects influencing the gestation length (GL) and the parturition conception interval (PCI) in Hanoverian warmblood horses and subsequently to estimate heritabilities for the GL and the PCI. Data comprised artificial insemination records of the years 2008–2014 from the National State Stud Celle, Germany, and corresponding foaling data from the Hanoverian Breeding Society, Germany. A total of 19,315 seasonal records including 10,294 mares and 276 stallions were available for GL and 10,244 records for PCI with 5881 mares and 234 stallions. The average GL was 341.7 ± 10.7 days. The fixed effects of the year and month of insemination, the age of the mare at the time of insemination, whether the mare had a foal with her from the previous season, the sex of the foal and the random effects of the mare and the stallion had a significant effect on the GL. For the effect of the month of insemination the GL was longest in the months of December to February and shortest in July and August. It was shortest in 2–4-year old mares and longest in mares > 19 years. Also GLs were longer if the mare did not have a foal at foot from the previous season than in mares with a foal with her. Pregnancies with colts were longer than those with fillies. The average PCI was 38.1 ± 25.9 days. Year and month of insemination, the age of the mare at the time of insemination and the mare as well as the stallion had a significant effect on the PCI. PCI was shortest in the months of December to February and increased until July and August. The PCI was longest in the youngest and the oldest age class of the mares. Heritabilities were estimated in linear animal models. A model including the maternal and paternal genetic effect resulted in heritabilities of 0.234 for the mare and 0.024 for the stallion for GL and 0.026 and 0.013 respectively for the PCI. Heritabilities for GL in a model including the maternal and direct genetic effects were 0.269 for the mare and 0.066 for the embryo. Mare-related effects seem to have the largest impact on GL, whereas environmental effects like a good post-parturition management highly influence the PCI.

1. Introduction

The day of parturition is difficult to predict in horses because of a very variable gestation length (GL). Reported average GLs range from 329.3 days in Warmblood horses (Millere, 2009) to 352.0 days in Thoroughbreds (van Rijssen et al., 2010) with an individual variation of 285–398 days resulting in viable foals. This variability in GL and the diversity of signs of impending parturition require a close surveillance of the mare at the end of her pregnancy. Horse breeders aim for one foal per year.

Some factors influencing GL are well analysed, like the year (Pérez et al., 2003; Valera et al., 2006; Langlois and Blouin, 2012) and month (van Rijssen et al., 2010; Dicken et al., 2012; Korabi et al., 2014) of breeding and foaling, the age of the dam (Valera et al., 2006; Satué et al., 2011; Langlois and Blouin, 2012; Kuhl et al., 2015), the sex of the foal (Davies Morel et al., 2002; Pérez et al., 2003; Aoki et al., 2013) and the parity of the dam (Winter et al., 2007; Satué et al., 2011; Aoki et al., 2013; Reilas et al., 2014). There are only few and ambiguous reports about the effect of other factors, like the age of the stallion (Davies Morel et al., 2002) or the stallion itself (Marteniuk et al., 1998; van Rijssen et al., 2010; Satué et al., 2011; Bene et al., 2014). An apparent difference in GL between breeds (Valera et al., 2006; Langlois and Blouin, 2012; Reilas et al., 2014) raises the question of the effects on the GL in Hanoverian warmblood, which has not been investigated before. Previous studies applying animal models reported a medium genetic impact on GL with heritabilities of 0.21–0.30 (Vassilev et al., 2002; Valera et al., 2006). Langlois and Blouin (2012) differentiated between the direct genetic and maternal genetic effect with heritability at

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0.08–0.115 for the foetus and 0.08–0.12 for the mare in different horse breeds.

With a GL of about eleven months, one month remains to get the mare pregnant again in order not to postpone the foaling date in the following breeding season. Therefore the factors influencing the parturition conception interval (PCI) are of great interest. The study of van Rijssen et al. (2010) found an average PCI of 32.0 ± 16.0 days for Thoroughbreds in New Zealand. The PCI was influenced by the month of mating and by the individual mare if all mares with more than two foalings were taken into account. The effect of the sex of the previous foal, the year of serving and the stallion did not show significance. The genetic impact on the PCI is unclear.

This study has the objective to analyse the fixed and random effects influencing the GL and the PCI in Hanoverian warmblood horses and, in addition, to estimate heritabilities for the GL and the PCI using a linear animal model for the maternal and paternal additive genetic effect. For the GL, heritability was also estimated using a model with the maternal and direct additive genetic effects.

2. Material and methods

The analysed data consisted of artificial insemination records of the years 2008–2014 from the National State Stud Celle, Germany. It contained the unique equine life number of the mare and the stallion as well as every date of insemination. The corresponding foaling data was provided by Vereinigte Informationssysteme Tierhaltung w.V., Verden/Aller, Germany (vit) and comprised all breeding outcomes for the mares and stallions registered by the Hanoverian Breeding Society. These records contained the unique equine life number and the birthday and the sex of the born foal. If no foal had been born, the reason for this, based on the breeders' information, was given. Pedigree information and the birthdays of mares and stallion were provided by vit as well.

GL was calculated as the difference between the last insemination date of a mare and the birthday of the foal in the following breeding season in days. GLs outside of a biologically acceptable range of 300–390 days have been excluded. The dataset included a total of 19,315 seasons where a foal was registered with its birth date. These seasons referred to 10,294 mares and 276 stallions. For the calculation of the PCI, the records were used only when the mare had foaled from a pregnancy of the previous season and started a new fertilisation round with a foal at foot. The PCI was calculated as the difference in days between the birthday of a foal and the last insemination date of a breeding season in the same year resulting in a pregnancy. This dataset included 10,244 seasons, 5881 mares and 234 stallions.

Linear mixed models were employed to analyse the statistical significance of fixed and random effects on GL and PCI using the MIXED procedure of SAS, version 9.4 (Statistical Analysis System, SAS Institute, Cary, NC). Tested fixed effects in a model with GL as the dependant variable were the year and month of insemination, the age of mare and stallion at the time of insemination, whether the mare had a foal at foot and the sex of the born foal. Tested fixed effects in a model the PCI were the year and month of insemination, the age of mare and stallion at the time of insemination and the sex of the foal from the previous season. Random effects were the mare and the stallion for GL and PCI, respectively. The following models were applied:

2.1. Model 1

$$Y_{ijklmnopq} = \mu + SEASON_i + MONTH_j + AGES_k + AGEM_l + FOAL_m + SEX_n + mare_o + stallion_p + e_{ijklmnopq}$$

where $Y_{ijklmnopq}$ = GL of the ijklmnopq-th season; μ = overall mean; $SEASON_i$ = fixed effect of the year (i = 1–7); $MONTH_j$ = fixed effect of the month of breeding (j = 1–6); $AGES_k$ = fixed effect of the age of the stallion at time of breeding in classes (k = 1–8); $AGEM_l$ = fixed effect of the age of the mare at time of breeding in classes (l = 1–9); $FOAL_m$ = fixed effect of a foal at foot (m = 1–2); SEX_n = fixed effect of the sex of the foal born (n = 1–2); $mare_o$ = random effect of the mare (o = 1–10,294); $stallion_p$ = random effect of the stallion (p = 1–276); $e_{ijklmnopq}$ = random residual effects.

2.2. Model 2

$$Y_{ijklmnop} = \mu + SEASON_i + MONTH_j + AGES_k + AGEM_l + SEXPRE_m + mare_n + stallion_o + e_{ijklmnop}$$

where $Y_{ijklmnop}$ = PCI of the ijklmnop-th season; $SEXPRE_m$ = fixed effect of the sex of the foal of the previous season (m = 1–2); $mare_n$ = random effect of the mare (n = 1–5881); $stallion_o$ = random effect of the stallion (o = 1–234); $e_{ijklmnop}$ = random residual effects.

Variance and covariance components and effects were estimated in a linear animal model with relationship matrices including at least eight generations per animal. The model included the maternal and paternal or direct (of the foal) additive genetic effects. The following linear animal model was applied for GL and PCI:

$$Y_{ijklmnopq} = \mu + SEASON_i + MONTH_j + AGES_k + AGEM_l + p - mare_m + p - stallion_n + mat_o + pat_p(foal_p) + e_{ijklmnopq}$$

where $Y_{ijklmnopq}$ = GL or PCI of the ijklmnopq-th season; p-$mare_m$ = random permanent environmental effect of the mare (o = 1–10,294 for GL or o = 5881 for PCI); p-$stallion_n$ = random permanent environmental effect of the stallion (o = 1–276 for GL or o = 234 for PCI); mat_o = additive genetic effect of the mare (n = 39,675), pat_p = additive genetic effect of the stallion (n = 1–39,675) or alternatively to the additive paternal effect $foal_p$ = additive genetic effect of the foal (n = 1–39,675); $e_{ijklmnopq}$ = random residual effects.

Heritabilities for the direct, paternal and maternal genetic effects were estimated with the following formula:

$$h^2_{sme} = \sigma^2_{Asmf}/(\sigma^2_{Asf} + \sigma^2_{Am} + \sigma^2_{ps} + \sigma^2_{pm} + \sigma^2_e + 2cov)$$

where σ^2_{Asm} = additive genetic variance of the stallion (s), mare (m) or foal (f); σ^2_{ps} = permanent environmental variance of the stallion, σ^2_{pm} = permanent environmental variance of the mare, σ^2_e = residual variance, cov = covariance between the respective additive genetic effects. Variance and covariance components were estimated using the software TM by Legarra et al. (2008). Parameter estimates were estimated from posterior distributions after a burn-in period of 50,000 iterations. The total length of the Gibbs chains was 1,000,000 samples. A sufficient length of burn-in was assured and convergence of the Gibbs chain was ensured through visual inspection of the sample plots against iteration number. Posterior means of additive genetic, environmental and residual (co)variances, heritabilities and additive genetic, environmental and residual correlations were calculated from unthinned chains of post-convergence samples.

3. Results

The average GL was 341.7 ± 10.7 days with a range from 300 to 390 days and lower and upper quartiles at 335 and 348 days (Table 1). The 5th and 95th percentiles were 326 and 360 days. Within the year and month of insemination, the age of the mare at the time of insemination, whether the mare had a foal with her from the previous season and the sex of the foal had a significant effect on the GL (Table 2). In addition, the random effects of the mare and the stallion had a significant influence as well. The proportion of the total variance of the GL was 0.403 for the mare and 0.030 for the stallion. GLs for sires mated to at least 10 mares ranged from 333.7 to 348.5 days. The GL was significantly lower in 2008 than in most of the other years, whereas significantly higher values were observed in 2009 than in 2010 and