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Original investigation

Gestation length variation in domesticated horses and its relation to breed and body size diversity

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ABSTRACT

The domestication process and selective breeding reportedly alter some life history variables. In horses, it has been claimed that gestation length is particularly variable. Some of the factors influencing gestation length are already known and can be grouped into environmental and genetic factors, but the effects of breed and body size have rarely been evaluated. In this study we tested the influence of breed and body size on gestation length for 25 horse breeds from Central Europe. The mean gestation length for all breeds was 342.3 ± 10.2 days and we found significant differences among breeds with a variation of up to 11 days. Body size did not show a significant correlation with gestation length. Our data suggest that breed affiliation explains part of the large variability of gestation length in horses.

Introduction

The process of domestication can generate changes in animals' life history, including reproductive cycles (Geiger et al., 2016; Herre and Röhrs, 1990). Horses, for example, have a large variation in their gestation length and some researchers suggest that it is even larger than in their wild relatives (Aoki et al., 2013). Full term gestation lengths ranging between 294 and 419 days with viable foals have been described (Rossdale, 1976; West, 1994) but periods considered "normal" range from 300 to 380 days (Aoki et al., 2013; Pérez et al., 2003).

Gestation length is much affected by diverse environmental and individual variables (Meliani et al., 2011). A significantly longer gestation length in mares bred at the beginning of breeding season compared to mares bred at the end of breeding season has been confirmed by various studies (Cilek, 2009; Davies Morel et al., 2002; Dicken et al., 2012; Langlois and Blouin, 2012; Meliani et al., 2011; Pérez et al., 2003; Rezac et al., 2013; Satué et al., 2011; Sevinga et al., 2004; Valera et al., 2006). As it has been found in other species with seasonal activity, e.g. in Przewalski's horses (Bronson and Heideman, 1994; Chen et al., 2008), mares show this foaling accumulation in spring to ensure optimal conditions for the offspring's survival.

Differences in gestation length are also related to the sex of the fetus. It is generally accepted that gestation length has a gender bias in horses and is about 1–2 days longer if the mare carries a colt (Aoki et al., 2013; Bene et al., 2014; Cilek, 2009; Heidler et al., 2004; Hintz et al., 1992; Langlois and Blouin, 2012; Marteniuk et al., 1998; Pérez et al., 2003; Sevinga et al., 2004; Staffe, 1935; Taveira and da Mota, 2007; Uppenborn, 1933; Valera et al., 2006; Van Rijssen et al., 2010). This is hypothesized to be caused by testosterone or chromosome linked effects (Cilek, 2009), differences in the interaction with endocrine control of parturition (Jainudeen and Hafez, 2000), or a more developed allontochorion in colts (Wilsher and Allen, 2003). In contrast to the high number of publications on this subject, two studies could not find differences between male and female foals (El-Wishy et al., 1990; Valente et al., 2006).

Several studies discuss the influence of additional factors such as climate (Mauch, 1937), stud farm where the mares are located during the gestation period (Aoki et al., 2013; Davies Morel et al., 2002; Langlois and Blouin, 2012; Van Rijssen et al., 2010), feeding management (Thorson et al., 2010; Uppenborn, 1933), type of insemination (Bene et al., 2014), inbreeding (Langlois and Blouin, 2012), length of last gestation period (Aoki et al., 2013), interval from ovulation to mating (Davies Morel et al., 2002), unspecified characteristics of the individual mare (Giger et al., 1996; Uppenborn, 1933; Valera et al., 2006; Van Rijssen et al., 2010), reproductive status of the mare (Van Rijssen et al., 2010), parity of the mare (Aoki et al., 2013; El-Wishy et al., 1990; Pool-Anderson et al., 1994; Sanchez, 1998; Staffe, 1935; Valente et al., 2006; Valera et al., 2006; Winter et al., 2007), age of the mare (Aoki et al., 2013;

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Bene et al., 2014; Bos and Van der Mey, 1980; Cilek, 2009; Davies Morel et al., 2002; Demirci, 1988; Guay et al., 2002; Heidler et al., 2004; Hintz et al., 1992; Kurtz Filho et al., 1997; Langlois and Blouin, 2012; Mauch, 1937; Sevinga et al., 2004; Valera et al., 2006; Winter et al., 2007), unspecified characteristics of the individual stallion (Bene et al., 2014; Mauch, 1937; Van Rijssen et al., 2010), age of the stallion (Davies Morel et al., 2002), artificial light (Caldas et al., 1994; Palmer and Driancourt, 1983), or year of breeding (Cilek, 2009; Langlois and Blouin, 2012; Valera et al., 2006).

Two additional factors are worth considering when examining variation on gestation length: breed and body size. Many of the studies related to gestation length were conducted with a single breed (Caldas et al., 1994; Cilek, 2009; Heidler et al., 2004; Hintz et al., 1992; Howell and Rollins, 1951; Pérez et al., 2003; Rollins and Howell, 1951; Taveira and da Mota, 2007; Van Rijssen et al., 2010; Winter et al., 2007) and results of those including different breeds are contradictory (Bene et al., 2014; Bos and Van der Mey, 1980; Langlois and Blouin, 2012; Roberts, 1986; Valera et al., 2006). One study showed significant variation of up to six days in the average gestation length among breeds (Bos and Van der Mey, 1980). One review reported differences of up to 13 days among the mean gestation length of different breeds (Satué et al., 2011). The authors argued, however, that the differences among previous reports might not only be caused by breed but also by differences in the way the gestation period was calculated, or differences in climate or photoperiod. On the other hand, no significant differences in gestation length among Hungarian horse breeds were reported by Bene et al. (2014).

Thus, previous studies provide a good overview of factors influencing gestation length regarding individual horse breeds; however, the influence of breed itself and body size remains unclear. In this study, we aim to investigate how those two factors influence the gestation length of the horse. Since research on gestation length of various horse breeds showed significant differences among breeds (Bos and Van der Mey, 1980; Langlois and Blouin, 2012; Valera et al., 2006), we firstly hypothesized that gestation length is a flexible life history variable in horses which does vary among breeds. Secondly, previous research on other domesticated species shows no significant correlation between size and gestation length in different sized breeds (reviewed in Clauss et al., 2014). Thus, we hypothesize that body size does not have a significant influence on gestation length.

Material and methods

In the present study, we used a total of 30,792 gestation lengths (15,599 female and 15,193 male newborns) from 25 horse breeds (Table 1). All gestation lengths were recorded by studbook societies in Germany and Switzerland (Rheinisches Pferdestammbuch e.V., Schweizer Freiberger Verband) which collected their data in Central Europe. Selected gestation lengths were pregnancies which resulted in one single viable foal during the breeding periods from 2000 to 2015. The duration of a gestation length was determined by the time interval between the last day of mounting/insemination and the day of parturition. Information on the age or parity of the mares was not consistently available in the dataset we collated. We restricted our dataset to gestation lengths ranging from 300 to 380 days due to previous studies referring to a normal gestation length in this range (320–360 in Laing and Leech (1975); Rossdale (1976), 300–400 in Pérez et al. (2003), 300–380 in Aoki et al. (2013)). In addition, only breeds with a sample size of at least ten individuals were used for the analyses. To visualize the position of wild equids in the allometric linear regression, we added average gestation lengths of four wild equid species from the literature to the figure but did not include them in the statistical analyses (Fig. 2).

Previous studies showed that foal gender and month of insemination have a significant influence on the gestation length of horses (see Introduction). Since we aimed to investigate the influence of the breed on gestation length, we calculated a model where the gestation length was linearly adjusted by the influence of foal gender and month of insemination (Linear model: Adjusted gestation length = $a + b^{*}sex + c_i{}^{*}month + \varepsilon$; a, b, $c_i \in R$; $\varepsilon \sim N(0,1)$; $i \in \{1,\ldots,12\}$). This adjustment is important to isolate the part of the gestation length which is explained by the breed only. We adjusted every recorded gestation length accordingly; in other words, all data presented in this study were adjusted in this manner. In 36 cases, the adjustment led to gestation lengths above the 380 days, which we still included in the following analyses. Differences in gestation lengths among breeds were evaluated using a parametric analysis of variance (ANOVA) followed by a post-hoc Tukey test and a Kolmogorow-Smirnow test of the residuals. To investigate the influence of body size on gestation length in our second analysis, we conducted an allometric linear regression. As a proxy for body size we used mean wither height of each breed according to breeding standards from the literature, since no individual height or weight was indicated in the available data. In contrast to wither height breed standards, no standard body mass data exist for all the breeds. We correlated the mean wither height to the breed's average gestation length using log-transformed data. The resulting coefficient in the allometric equation is stated, including its 95% confidence intervals in brackets. All statistical analyses were performed using Statistica (Version 12, StatSoft Inc., Tulsa, USA) and the significance for all tests was set at $\alpha = 0.05$. Results are displayed as means ± standard deviation.

Results

The gestation length mean for the 25 breeds was 342.3 ± 10.2 days, with a range between individual animals of 301–388 days (Table 1). The ANOVA resulted in significant differences between the 25 breeds ($p < 0.0001$, $F = 13$, for sample size see Table 1) with a maximum mean gestation length of 351 days in Welsh Cobs and a minimum mean gestation length of 340 days in Friesians leading to a variation of 11 days among all means (Fig. 1). The post-hoc Tukey tests resulted in 9 out of 300 comparisons which were significant, mainly involving comparisons of Welsh Cobs and Rhenish Warmbloods with other breeds.

Our second analysis, the allometric linear regression, showed no correlation between mean wither height and mean gestation length in our sample (Fig. 2). The allometric exponent was low with mean wither height scaling to gestation length$^{-0.005}$ (95% CI: −0.03–0.02, $r^2 = 0.007$, $p = 0.67$).

Discussion

Breed affiliation is an important factor influencing variation in gestation length in horses, whereas the effect of body size is not significant. However, parturition time in horses is difficult to predict due to its high variability and unclear indicating signs.

Not all factors which potentially influence gestation length have been examined so far. In this study, we tested the influence of breed and body size on gestation length among 25 breeds.

Differences in calculation of gestation length might introduce some error when comparing studies. Gestation length is often calculated, like in our study, as the period between last mating (or insemination) and parturition. This period, however, is not equivalent to the true gestation length: the period between ovulation and parturition. Galisteo and Perez-Marin (2010) reported that in