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Original article

Gestational length in Carthusian broodmares: effects of breeding season, foal gender, age of mare, year of parturition, parity and sire

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Abstract

The length of gestation in Carthusian broodmares was calculated on the basis of 339 spontaneous full-term deliveries taking place in the 8-year period 1998-2005 from 158 broodmares and 29 stallions in a major farm of Spanish horses of Carthusian strain in southern Spain. Ultrasonography was used to determine follicular dehiscence, 1st day of pregnancy and to confirm conception in mares. Mean GL was 332.4 ± 12.1 days, and a normal interval of 297-358 days was established for this breed. GL records were grouped on the basis of foal sex (colts or fillies), mating month (between November and January; February and April; May and July), age of the mare (4 to 7 years; 8 to 12 years; 13 to 17 years), breeding year, stallion and parity (primiparous vs. multiparous). GLs were 12.9 days shorter in mares mated between May and July than those mated between November and January and 15.3 days in mares mated between February and April ($p<0.001$). Mares aged between 8-12 years had 5.3 days shorter GLs than those aged between 13-17 years ($p<0.05$). Pregnancy was significantly 5.7 days longer when the mare gave birth to colts than fillies ($p<0.05$). GL was 14.5 days longer in primiparous than in multiparous mares ($p<0.001$). No statistical differences in GL were found between the studied years. This study shows the influence of certain stallion on GL.

Key words: gestational length, breeding season, foal sex, parity, Carthusian mares

Introduction

Gestational length (GL) is a physiological variable of economic importance in most domestic species. The management of a high value stock requires the precise prediction of the moment of parturition. Likewise, knowledge of the GL is clinically important, as it is considered an accurate criterion in assessing fetal viability after delivery and it helps to classify the foal as dysmature (Koterba 1990).

Marked interindividual and intraindividual differences exist in GL in mares. Up to now, GL data have been reported for Thoroughbreds (Hintz et al. 1992, Davies-Morel et al. 2002, Duggan et al. 2008,

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Elliot et al. 2009, Sharma and Dhaliwal 2010), Freibergers (Giger et al. 1997), Lipizzaners (Heidler et al. 2004), Friesians (Sevinga et al. 2004), Quarter Horses (Guay et al. 2002, Duggan et al. 2008), Standardbreds (Marteniuk et al. 1998, Villani and Romano 2008), Criollo (Winter et al. 2007), Pantaneira (Zúccari et al. 2002), Andalusians (Valera et al. 2006), Arabians (Demirci 1988, El-Wishi et al. 1990, Valera et al. 2006, Cilek 2009, Meliani et al. 2011) and Andalusians of Carthusian strain (Pérez et al. 2003). In all these studies, GL ranges between 330 and 350 days. Ponies tend to have a shorter GL (Ropiha et al. 1969, Rossdale et al. 1984, Ousey et al. 1998) and also Przewalski horses (Monfort et al. 1991), with means of 320 and 326 days, respectively. Longer GLs have been described for mares bred with donkeys (Holm 1967, Arora et al. 1983, Giger et al. 1997). The range provided as normal for a mare is wide, and more limited variation should be known for each breed under determined breeding and climatic conditions, such as latitude and photoperiod.

GL shorter than 320 days are generally considered short and a greater risk of resulting in a premature, often immature foal, with enhanced potential of developing life-threating diseases (Koterba 1990). In fact, most foals with GLs shorter than 300 days are nonviable, due to lack of fetal organ development (Rossdale 1976). The main causes implied in short GLs are placentitis and placental insufficiency, twin pregnancy and umbilical cord torsion (Davies-Morel 2008).

By contrast, GLs longer than 365 days are considered prolongated and could derive from placental insufficiency or nutritional deficiency of the broodmare during pregnancy (Koberba et al. 1990), although they might result in viable foals. In such cases, the newborn foal is postmature and might display weakness, irregular dental eruption, hoof overgrowth and inadequate transference of colostral passive immunity (Putnam et al. 1991, Rossdale 1993). Furthermore, a long GL could lead to an excessive size in the foal and poor muscle development (Putnam et al. 1991, Rossdale 1993). Braunton (1990) described a GL of 403 days in a mare, although the longest GL resulting in a live foal was of 419 days (West 1994). In main lines, neither maternal nor fetal complications are necessarily observed in those pregnancies exceeding 400 days. The aim of this study was to determine average GL and normal variability in Carthusian mares and the possible influences of foal sex, breeding month, age of the mare, breeding year, stallion and parity on GL.

Materials and Methods

This investigation was carried out on the stud farm "Hierro del Bocado" in Jerez de la Frontera, Cádiz (Spain), situated at latitude 36°41' north and longitude 06°09' west. We also presented our own data obtained from a total of 339 pregnancies recorded between 1998-2005 from 158 broodmares and 28 stallions. From the first day of oestrus, ovarian ultrasonography was performed every 24 h. The presence of a preovulatory follicle (≥ 3.5 cm.) was taken as the start of breeding. Early pregnancy diagnosis was made on day 14 by ultrasonography. GL was calculated as the time from ovulation to parturition (Davies-Morel et al. 2002). The influence of different factors, such as foal sex, breeding month, age of the mare, breeding year, stallion and parity are presented. GL records were grouped on the basis of foal sex (colts or fillies), mating month (between November and January; February and April; May and July), age of the mare (4 to 7 years; 8 to 12 years; 13 to 17 years), breeding year, stallion and parity (primiparous vs. multiparous). One-way repeated-measure ANOVA was used to examine the effect of foal sex, breeding month, age of the mare, breeding year, stallion and parity on gestation length by SPSS 7.5 for Windows. When differences were significant ($p < 0.05$), Tukey's multiple comparison test was used. Results were expressed as mean ± SD.

Results

Results are presented in Tables 1 and 2. Mean GL was 332.4 ± 12.1 days. GLs were significantly shorter in mares mated between May and July (320.3 ± 9.7 days) than those mated between November and January (333.2 ± 13.6 days) and between February and April (335.6 ± 10.0 days) ($p<0.001$). Mares aged between 8-12 years (330.8 ± 11.0) had shorter GLs than those aged between 13-17 years (336.1 ± 8.9 days) ($p<0.05$). Pregnancy was significantly longer when mares gave birth to colts (336.8 ± 11.0 days) than fillies (331.1 ± 12.8 days) ($p<0.05$). GL was longer in primiparous (345.9 ± 6.1 days) than in multiparous mares (331.4 ± 6.2) ($p<0.001$). No statistical differences in GL were found between the studied years. 18 stallions show a range of GL below 324-333 days, and 10 of them 334-352 days.

Discussion

Breed

Average values obtained in Carthusian mares were shorter than those obtained in different breeds such as, Thoroughbreds (Hintz et al. 1992, Davies-Morel et al. 2002, Kurtz Filho et al. 1997, Duggan et al. 2008, Sharma and Dhaliwal 2010), Freibergers (Giger et al. 1997), Lipizzaners (Heidler et al. 2004), Quarter Horses (Pool-Anderson et al. 1994, Guay et al. 2002, Duggan et al. 2008), Hannoverians

Table 1. GL in Carthusian broodmares in relation to sex of foal, age of mare, breeding season, parity and year of parturition.

	N	Minimum	Maximum	Mean	SD
GL (days)	339	297.0	358.0	332.4	12.1
			Sex of foal		
Colts	168	314.0	358.0	336.8	11.0
Fillies	171	297.0	356.0	331.1	12.8
* p < 0.05					
			Age of mare		
4-7 years	36	297.0	356.0	332.0**	13.6
8-12 years	198	311.0	358.0	330.8	11.0
13-17 years	105	319.0	349.0	336.1***	10.0
**, *** p < 0.05					
			Breeding season		
November-January	27	314.0	356.0	333.2**	13.6
February-April	119	311.0	358.0	335.6	10.0
May-July	193	297.0	331.0	320.3***	9.7
**; ***p < 0.001					
			Parity		
Multiparous	173	314.0	356.0	345.9	6.1
Primiparous	164	311.0	358.0	331.4	6.2
* p< 0.001					
			Year of parturition		
1998	63	314.0	361.0	335.3	9.7
1999	71	318.0	352.0	332.8	8.1
2000	58	319.0	356.0	335.3	8.2
2001	69	316.0	357.0	334.9	9.2
2002	44	320.0	354.0	335.1	8.1
2003	10	325.0	346.0	333.5	7.2
2004	6	317.0	339.0	330.8	7.5
2005	18	324.0	355.0	336.8	8.5
NS					

1998, Villani and Romano 2008), Criollo (Winter et al. 2007), Pantaneira (Zúccari et al. 2002), Andalusians (Valera et al. 2006) and Arabians mares (Valera et al. 2006, Cilek 2009).

Our data for Carthusian broodmares are shorter than those provided by Pérez et al. (2003), although the two studies were carried out in this same breed from the south of Spain. These differences could derive from the influence of environmental factors. Pérez et al. (2003) did not mention the environmental conditions in their article, and therefore no direct comparison with our results could have been made. However, they presented data from 1994, which was the last of a 5-year dry period, and this environmental condition might have influenced their results. In contrast, other investigations carried out on Arabian (El-Wishy et al. 1990, Meliani et al. 2011) and Thoroughbred mares (Allen et al. 2004) have presented values similar to those obtained in the Carthusian mares of our study. Finally, in Friesian mares, Sevinga et al. (2004) showed low values of GL. The differences between the results might be related to the breed, climatic conditions, geographical region, latitude and photoperiod in which the above mentioned studies were carried out.

Breeding season

We found GLs of 333.2 ± 14.12, 335.6 ± 10.04 and 320.3 ± 9.7 days in Carthusian broodmares mated between November and January, February to April and May to July, respectively. Our data are in agreement with most of the previous investigations concerning moment of mating (Ropiha et al. 1969, Arora et al. 1983, Roberts 1986, Vandeplassche 1986, Hintz et al. 1992, Marteniuk et al. 1998, Pérez et al. 2003, Satué 2004, Cilek 2009). In all of these investigations, a significant reduction in GL in mares mated at the end of breeding season in comparison to mares mated at the beginning of the season was found. Indeed, previous authors reported longer GLs when the mares were mated in January or February, compared with mares mated between July and November.

The same results have been found in Carthusian Spanish mares in the south of Spain (Pérez et al.

Table 2. GL in Carthusian broodmares in relation to sire.

	N	Minimum	Maximum	Mean	SD
			Sire		
Stallion 1	10	341.0	374.0	353.0*	10.2
Stallion 2	15	334.0	372.0	347.7	9.4
Stallion 3	4	362.0	377.0	368.3*	7.1
Stallion 4	3	346.0	361.0	352.7	7.7
Stallion 5	31	332.0	367.0	351.9	8.1
Stallion 6	13	326.0	371.0	348.1	12.7
Stallion 7	8	341.0	359.0	351.5	6.3
Stallion 8	5	344.0	366.0	352.8	8.3
Stallion 9	6	338.0	351.0	345.0	4.7
Stallion 10	8	336.0	355.0	346.8	6.4
Stallion 11	5	330.0	360.0	349.2	11.8
Stallion 12	3	342.0	363.0	350.7	10.9
Stallion 13	11	341.0	366.0	348.7	7.9
Stallion 14	50	336.0	372.0	350.7	8.3
Stallion 15	2	346.0	360.0	353.0	9.9
Stallion 16	42	335.0	366.0	350.9	7.2
Stallion 17	9	340.0	357.0	348.4	5.9
Stallion 18	30	329.0	361.0	346.0	8.1
Stallion 19	3	335.0	343.0	340.0	4.4
Stallion 20	3	348.0	359.0	354.0	5.6
Stallion 21	12	344.0	360.0	352.6	5.2
Stallion 22	7	339.0	358.0	351.6	6.9
Stallion 23	9	348.0	360.0	352.6	4.7
Stallion 24	7	344.0	360.0	349.3	5.5
Stallion 25	7	336.0	357.0	345.6	8.0
Stallion 26	7	344.0	363.0	354.4	8.3
Stallion 27	13	334.0	362.0	349.8	10.0
Stallion 28	2	349.0	349.0	349.0*	0.0
* p < 0.05					

2003). These authors observed that GL was 11 days longer in Carthusian broodmares bred in winter, at the beginning of the breeding season, than at the end of the season, in June. This represents an increase of 2.75 days per month. Our dates indicated that GL at the end of the breeding season is significantly shorter, with a reduction of 12.9 days in comparison to mares mated at the beginning of the season. Similarly, Marteniuk et al. (1998) found a significant decrease in GL in Standardbred mares which conceived between April and June. In the same way, Ousey et al. (2000), in ponies, noticed that gestations were shorter in May and July, increasing in September. In contrast, Davies-Morel et al. (2002) and Sharma and Dhaliwal (2010) found the shortest GL in mares bred in January. These authors noted that Thoroughbred foals born in January had a GL of 330.8 ± 2.90 and 335.79 ± 1.29 days, while foals born in April had a GL of 347.3 ± 2.90 and 346.08 ± 0.77 days, respectively.

As with other species with seasonal activity, the mare usually gives birth during the spring season in order to assure the best conditions for the survival of the offspring (Bronson and Heideman 1994). However, temporal coincidence between the mare's reproductive physiology and producers; reproductive interest is not always achieved.

Some equine farms prefer births to occur at the beginning of the year, which can be achieved by means of the application of artificial light treatments during the days of the season with less luminosity in order to increase the photoperiod. With the use of this treatment, the conception season goes forward and, as consequence, the mares can give birth in the first months of the year. The additional application of light reschedules the season of ovarian activity (Scraba and Ginther 1985), since the photoperiod influences the date of the first ovulation after the winter anestrus. Additionally, treatment with artificial light advances significantly the date of the first ovulation (Vázquez et al. 2004).

The influence of the moment of mating seems to derive from environmental factors, such as feeding conditions and temperature. It has been suggested that nature attempts to bring the timing of parturition back to the ideal, i.e., early spring, and this must be achieved by shorter or longer GLs (Evans and Torbeck 1998). Hence, favorable weather conditions affect the nutritional value of grasslands and, as a result, the mare might have a better nutritional intake and the foal would require less time to achieve the proper weight for birth. Valera et al. (2006) noted that the mating period accounts for 4.4% of the variance in the

GL of Andalusian and Arabian broodmares in the south of Spain. In our opinion, the differences between the above mentioned investigations could be partially explained according to the different climatic conditions over the years and/or the country.

Geographic area, climate, day length and environmental temperatures might partially explain the differences observed in GLs in the different investigations since that regions of similar latitudes, have similar GLs and are affected by similar factors (Kurtz Filho et al. 1997, Davies-Morel et al. 2002, Winter et al. 2007). We have found that the shortest GL in the Carthusian broodmares appear when the animals were mated between May and July. This result could be related to the high mean environmental temperature (22.08 ± 3.97°C) and low relative humidity (58.77 ± 2.06%) (Satué 2004).

Year of parturition

There is a commonly held belief that GL is affected by the year (Cilek 2009). Dry years with high average temperatures have a negative effect on GL. In this way, Valera et al. (2006) stated that dry years or those with more extreme temperatures are the years with GLs longer than expected. The main reason could be the influence of the nutritional quality of feedstuffs. During periods of bad winter weather, feeding would have been suboptimal and irregular with regard to proteins, vitamins and total calories. This fact could lead to an early end of pregnancy as a mechanism for adjusting to the adverse climatic and nutritional conditions (Pérez et al. 2003). However, we did not find any significant difference in GLs in the Carthusian broodmares studied between 1998 and 2005, despite the differences in climate, results which disagree with those presented previously by Valera et al. (2006). One plausible explanation could be the feed supplementation when the environmental conditions were not adequate for the mares. Nevertheless, feeding of the Carthusian mares throughout the years of the study was similar, so the conclusion refers to the rangeland management practices, and not farms that make feed available regardless of the conditions for any particular year.

Sex of foal

In Carthusian broodmares, GL was 5.7 days longer in colts than fillies. It is accepted that male-product pregnancies are slightly longer (2-3 days of mean) than female counterparts (Zwolinski 1964, Rophila et al. 1969, Roberts 1986, Hintz et al. 1992, Hevia et al. 1994, Marteniuk et al. 1998, Davies-Morel et al. 2002, Pérez et al. 2003, Satué 2004, Sevinga et al. 2004, Valera et al. 2006, Cilek 2009, Sharma and Dhaliwal 2010). Despite theses differences, Valera et al. (2006) showed that gender only accounts for 0.430% of the total variation of GL in Andalusian broodmares. The reason for the variation of GL associated with the gender of the foal has not yet been completely elucidated. However, it is agreed that male body development is greater than female's and therefore, if the birth occurs when the fetal development is complete, the GL of a colt would be longer (Wilser and Allen 2003). These later authors found that colts have a better developed placenta and these authors interpreted this finding as a faster development during pregnancy. However, Elliott et al. (2009) showed that GL is not strongly associated with the body weight of the foal at birth. Moreover, foal birth weight is a reflection of the balance between fetomaternal contact and placental efficiency. Increases in fetomaternal contact are correlated to reductions in placental efficiency, which may reflect the ability of the placenta to modify its exchange capabilities and hence its influence upon fetal growth (Wilsher and Allen 2003). Furthermore, it has been postulated that the difference in foal gender is due to different endocrine functions of the fetus, interacting differently with the control of parturition (Jainudeen and Hafez 2000). In human pregnancies, this fact has been associated with differences in androgen action (de Zegher et al. 1999) and to sex-chromosome-linked effects (Pergament et al. 1994, Monteiro et al. 1998). However, there are two older reports which failed to document a significant association between foal gender and GL in horses (Arora et al. 1983, El-Wishi et al. 1990).

Age of the mare

We found GLs of 332.0 ± 13.6, 330.8 ± 11.0 and 336.1 ± 8.9 days in Carthusian broodmares belonging to three age groups: between 4-7, 8-12 and 13-17 years, results similar to those obtained by Valera et al. (2006). In our opinion, the shortest duration in the second age group indicated the full development of the reproductive system of the Carthusian broodmares. Younger animals, particularly if they are around 4-5 year-olds might not be completely developed yet, as the growth rate of Carthusian and Andalusian horses is slower than in other equine breeds. On the other hand, mares older than 13-14 years usually require more mating per conception, which is explained by progressive degenerative changes in the endometrium and increased susceptibility to infections (Pashan and Allen 1979, Rossdale et al. 1992, Wilsher and Allen 2003, Gluckman and Hanson 2004). The degenerative changes in the endometrium might potentially reduce its nutritive capacity for the development of the fetus (Satué 2004).

Although the age of the mare has been considered an important factor determining GL in most reports (Zwolinski and Siudinski 1965, Akkayan and Demirtel 1974, Bos and van der Mey 1980, Demirci 1988, Satué 2004, Valera et al. 2006), some discrepancies existed. Indeed, several authors failed to detect differences in GL when comparing mares of different ages (Hintz et al. 1992, Kurtz Filho et al. 1997, Davies-Morel et al. 2002, Guay et al. 2002, Pérez et al. 2003, Winter et al. 2007).

Parity

According to some authors, the number of births or parity also influences GL (Pool-Anderson et al. 1994, Cacic et al. 2002). Pool-Anderson et al. (1994) described a 10 days longer GL in primiparous *vs.* multiparous Quarter Horse mares. In our study we found significantly longer GLs in primiparous Carthusian broodmares (345.9 ± 6.10 days) in comparison with multiparous mares (331.4 ± 6.20 days). In contrast, one previous report failed to record significant differences (Arora et al. 1983). It could be considered that primiparous mares, which are usually young mares, have longer GLs because they are not anatomically and/or physiologically prepared.

It has been suggested that nature attempts to bring the timing of parturition back to the ideal (i.e. early spring), and this may be achieved by shortening GLs (Evans and Torbeck 1998). Favourable weather conditions affect the nutritional value of grasslands, the mare will have a better nutritional intake and the foal will need less time to reach the proper weight for birth (Davies-Morel et al. 2002). Langlois (1973) indicated that well-nourished mares have shorter gestational lengths than mares on maintenance diets. The decrease in quality and quantity of supplemental feed and the deterioration of pastures due to overgrazing and inadequate fertilization are associated with increase in GL. Moreover, mares with higher body condition scores averaged a 4-day shorter pregnancy. In addition, mares with body conditions of four or less have overall pregnancy rate reductions as large as 20% less than mares in better body condition. Moreover, early pregnancy losses are significantly greater in mares with body scores of four or less (Howell and Rollins 1951, Heneke et al. 1984).

More recently, it has been demonstrated that mares that rely on native pasture land for feed have more significant variations in GL than mares fed with commercial alfalfa hay or timothy grass. This variation of the type of nourishment, may be a major factor in the differences or conflicting results found among the diverse studies. Nevertheless, there is no cientific consensus in this area (Guay 2001, Guay et al. 2002).

Sire

Sire effects have been analyzed in relation to GL. Marteniuk et al. (1998) found that GL after mating with certain sires was consistently shorter than 340 days in duration, whereas GL after mating with other sires was consistently longer than 350 days, as has been observed in Carthusian broodmares. As a conclusion of their results, the authors recommended that sires associated with exceptionally long GLs should be bred early in the reproductive season, whereas those associated with short GLs should be used later. The main cause implied in the relationship between sire and GL is unclear, although the influence of fetal size should be considered. In this way, Roberts (1986) stated that the fetus was a main determinant of GL, except possibly in those cases of great breed-related size discrepancy between the sire and the dam. Similarly, Vandeplassche (1986) noted that the sire and the mare might increase or decrease GL. In contrast, a significant influence of the sire on GL was not found by Ropiha et al. (1969), El-Wishy et al. (1990) and Davies-Morel et al. (2002). The later authors demonstrated that the effect of stallion age was not significant on GL, probably because there is no scientific evidence to suggest that sperm viability, although affected by age, has any effect on the GL of a viable fetus.

Conclusions

The analysis of the effect of age of mare, sex of fetus, parity, stallion and breeding season on GL in diverses equine breeds, as well as in Carthusian mares reveal contradictory results. We conclude that foal sex, breeding season (pregnancy in mares mated between November-January was 12.9 days longer than mares mated in May and July), age of the mare (pregnancy in mares aged between 8-12 years was 5.3 days shorter than those between 13-17 years), stallion and parity significantly influence GL in Carthusian mares. In our study, GL was not influenced by the year breeding. Determination of the precise moment of parturition is important, as the preparation of staff, facilities, supplies and mares for parturition could be more effective and efficient if we have better information on the expected day of delivery.

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