Veterinary Record Open

Occurrence of preterm calving in Great Britain and associations with milk production and reproductive performance in dairy cattle

Angela Filipa Damaso,[1] Martina Velasova,[1] Steven Van Winden,[1] Yu-mei Chang,[2] Javier Guitian[1]

To cite: Damaso AF, Velasova M, Winden SV, *et al*. Occurrence of preterm calving in Great Britain and associations with milk production and reproductive performance in dairy cattle. *Veterinary Record Open* 2018;**5**:e000221. doi:10.1136/vetreco-2017-000221

Received 30 January 2017
Revised 26 May 2017
Accepted 7 August 2017
Published Online First 20 January 2018

ABSTRACT

This study describes the occurrence of preterm calving in Great Britain and evaluates its associations with subsequent milk production and reproductive performances and survival on farm of dairy cows. A total of 53 British dairy farms and 5759 animals with detailed breeding and milk recording data available were used to form two study groups: preterm calving (calving occurring between days 266 and 277 of gestation) and full-term calving (calving occurring at 278 days of gestation and over). Mixed effects models were implemented to compare milk production, clinical cases of mastitis and number of services per conception between groups. Kaplan-Meier curves and Cox regression analyses compared time from calving to conception, calving interval and survival on farm between groups. Preterm calving cows showed significantly lower milk yield (P<0.01) and butter fat per cent (P=0.02), increased milk protein per cent (P=0.01), longer survival on farm (P<0.01), and a tendency for shorter calving to conception intervals and fewer services per conception, although other factors were involved in the reproduction outcomes. Experiencing a preterm calving is associated with lower milk production and longer survival times on farm. Potential risk factors for preterm calving, such as infectious diseases, diet and husbandry practices, should be further investigated.

INTRODUCTION

The gestation length (GL) of dairy cattle breeds has been subject to research for several decades. This trait is susceptible to genetic selection in cattle,[1–3] with direct and indirect heritability effects in Holstein-Friesian (HF) cattle of 0.201–0.210 and 0.055–0.073, respectively.[4] This indicates that GL is more dependent on the genetics of the calf, namely the size and the sex of the calf, and the occurrence of twin pregnancy,[3 5 6] than on the genetics of the dam.[4] However, environmental factors have also been found to affect GL; summer months have been associated with shorter gestations.[7]

In 1965, GL averaged 280 days in 5207 gestations worldwide.[1] In 1992, the mean GL of 13,612 calvings in Florida was also 280 days, and a positive genetic correlation between milk yield and GL was reported.[8] In the USA data from over 11 million parturitions resulted in a mean GL for Holstein heifers and cows of 277.8 and 279.4 days, respectively,[3] suggesting that GL might be currently shortened in some populations of HF cattle. The same study reports shorter gestations occurring more frequently in October conceptions, in multiple births and in milk yields of ≤8000 kg, which suggest that both genetic and environment factors may be involved in the causes of shorter gestations. A later study reported little carryover from the dam to the traits observed on the offspring, supporting a strong indirect heritability effect in the population studied.[9]

Increased milk yields have been associated with increased GL, calving ease, stillbirth, culling[9] and lower reproductive performance, mainly due to occurrence and persistence of periods of negative energy balance.[10–12]

GLs between 274 days and 283 days were associated with optimal days open.[9] Calving ease and stillbirth rates were optimal for GL between 275 and 277 days.[4] Gestations 9–15 days shorter than the average have been linked to increased stillbirth of up to 55.3 per cent in Holstein cattle[13] and poorer growth traits in calves.[14] More recently in New Zealand dairy farms, animals born following shorter GL (265–273 days) were 3 per cent more likely to die in the perinatal period, but if reached maturity, these animals showed improved fertility, lower milk yield and solids and similar survival times to those born from intermediate GL.[15] A decrease in milk yield[16] and conception rates[17] has been associated with abortion, which is defined as the expulsion of a dead or non-viable fetus at any stage of pregnancy before the time of normal parturition.[18] A definite number of days is often

[1]Department of Pathobiology and Population Sciences, Royal Veterinary College, London, UK
[2]Research Support Office, Royal Veterinary College, London, UK

Correspondence to
Dr Angela Filipa Damaso; adamaso@rvc.ac.uk

avoided in the definitions of abortion, but in dairy cows, calf viability has been reported as good within 14 days of anticipated calving date.[19] In the present study, a preterm calving was defined as a calving occurring between 266 and 277 days of gestation. The consequences of preterm calving on milk production and reproductive performance have not yet been extensively described in the British dairy cattle population.

Therefore, the aims of this study were to describe the occurrence of preterm calving in Great Britain (GB) and evaluate the associations between a preterm calving and subsequent milk production, reproductive performance and survival on farm of HF and British-Friesian (BF) cattle population in GB.

MATERIALS AND METHODS

Study population and study design

A stratified random sampling was carried out for a cross-sectional study[20], from a sample frame of 10,491 dairy farms registered with AHDB Dairy, a levy-funded organisation representing approximately 95 per cent of the dairy farms in GB. A total of 1483 British dairy farms were initially selected and the producers were contacted via letter in the post. Out of the 553 respondents, 225 farms agreed to participate, from which 84 had individual milk recording records available and permission was given to access the data (Fig 1). The sampling method allowed inclusion of different farm management systems, including pasture-based feeding systems in summer months and silage-fed in free stall all-year-round, and reproductive systems based on block calving, all-year-round calving and other types.

The present study used a retrospective cohort study design, where data related to individual cow reproductive performance and individual cow milk recording were used to study the associations between preterm calving and the outcome variables.

Data collection and inclusion criteria

The software InterHerd+ (PAN Livestock Services, Reading, UK) was accessed on July 8, 2015 and was used to filter historic fertility records of individuals that conceived between January 1, 2011 and December 31, 2014 and individual cow milk recordings from the same time interval, provided by the company National Milk Records. The files were then exported to Microsoft Excel 2010 and merged using IBM SPSS Statistics V.23, according to the calving dates recorded on both data sets, accounting for farm and animal identification.

The data required screening to reduce errors related to electronic data entry at the farm level. Data entry was done directly by farmers or farm employees, either automatically, manually from farm paper copies or a combination of both.

Farm inclusion and data quality screening were done in three stages to reduce bias due to 'default' GL on natural insemination, to eliminate known recording errors due to bulk entry and to eliminate biologically unlikely records: (1) inclusion of farms, based on the use of artificial insemination only (gestations occurring from a natural insemination are calculated automatically by the data management software (DMS) as 280 days long based on the record of the calving date); (2) inclusion of farm-years, where data were split into four years (2011–2014), and each farm-year had to match the following criteria: (a) services or calvings recorded on the same date in each farm had to account for less than 5 per cent of the herd, to exclude data entry in bulk; and (b) no more than 2 per cent of GL over 295 days, as GLs over 295 days in cattle are biologically unlikely; and (3) inclusion of individual records, which had to observe the following criteria: (a) only Holstein, HF or BF dam breeds, to reduce dam-dependent GL variation; (b) breeding dates with interservice intervals of one day (cows can be in heat during 30 hours,[21] but date of conception was assumed to be the first service date) and over 17 days, to discount for conceptions occurring in previous inseminations; (c) conceptions resulting from any sire breeds; (d) first available lactation records of each cow when more than one lactation had been recorded on farm, to avoid repeated measures, since the majority of cows did not have multiple lactation records during the study period and this created computational difficulty; and (e) if multiple milk recordings were available, the last milk recording data of the lactation selected in (d) were used.

A total of 84 farms used artificial insemination only. The second stage of data quality check yielded 60 farms, 142 farm-years and over 38,000 records. The third stage of data cleaning resulted in 53 farms, 125 farm-years and a total of 5759 calvings suitable to use in the analysis (Fig 1).

Outcome variables and data management

Individual GLs were calculated as the number of days between the calving and service dates, and two *types of calving* groups were created: the preterm calving (PTC) group, comprising cows that had experienced a GL of 266–277 days; and the full-term calving (FTC) group, consisting of cows that had delivered a full-term calf (GL of 278+ days).

Milk yield and composition were compared between groups using cumulative milk yield (CumMY, kg)—calculated by the software based on all available individual milk yields from that lactation and representing the total (not predicted) raw milk production in the subsequent lactation of the calving event; average milk protein (MProt, per cent), average butter fat (BFat, per cent) and average somatic cell score (SCS, cells/ml)—averages of the cumulative parameters of all the milk recordings in that lactation; and the number of cases of clinical mastitis in the lactation following a calving event. The somatic cell count data (directly exported from the DMS) were not a normally distributed variable; for this reason it was transformed into its natural logarithm, the SCS,[22] which was normally distributed.

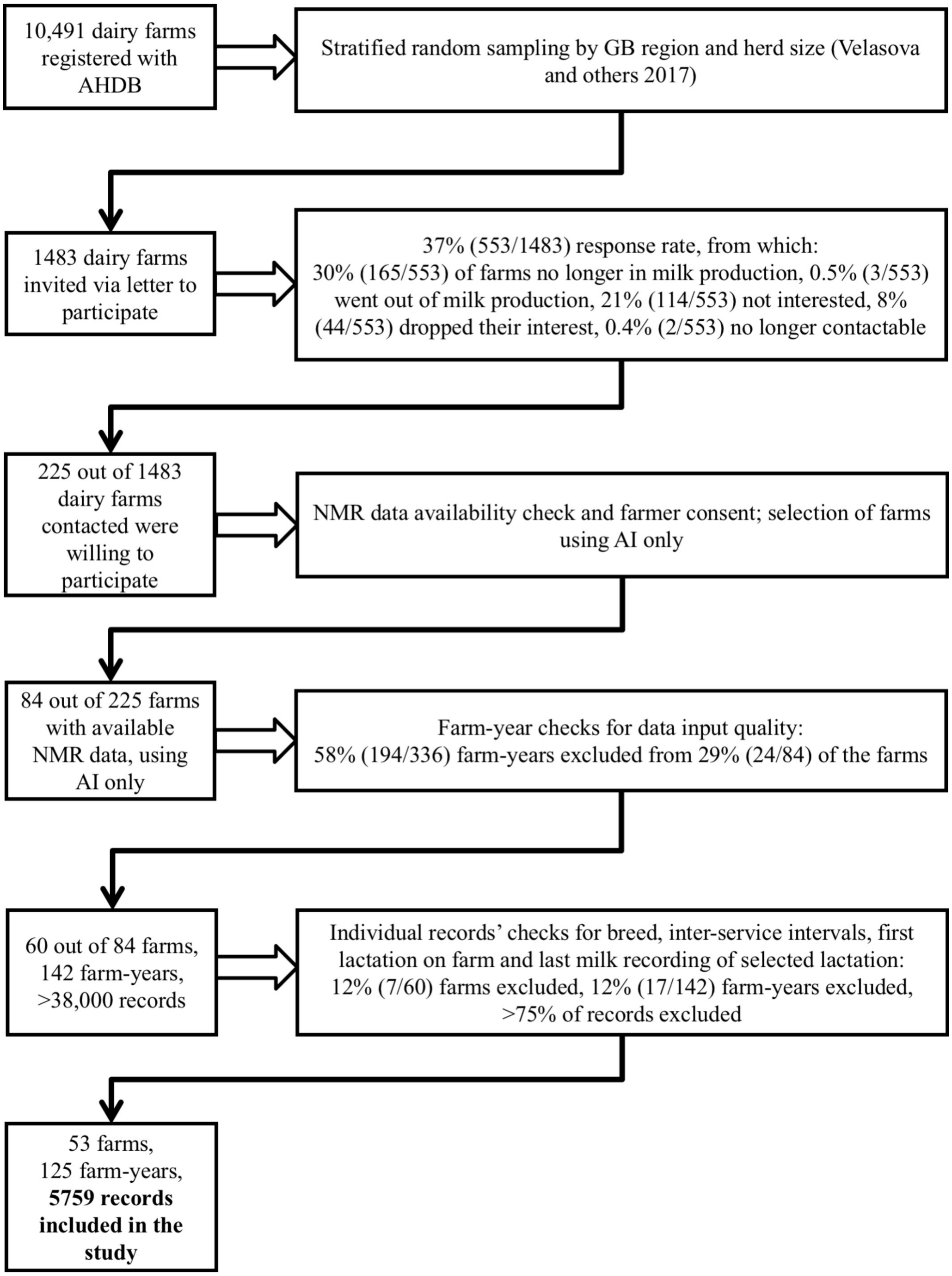

FIG 1: Flow chart summarising the stages of the study population from the initial sample to the final sample (left-hand side boxes) and the steps and reasons for selection of farms and records (right-hand side boxes). AI, artificial insemination; GB, Great Britain; NMR, National Milk Records.

The occurrence of clinical mastitis was defined when at least one episode of mastitis was recorded and transformed into a binomial variable ('Yes' or 'No'). The absence of mastitis records in the system accounted for 88 per cent (n=5069) of the total number of records.

Reproductive performance and fitness traits in the herd were compared between the two groups using four outcome variables: (1) number of services per conception=a variable that required a subsequent conception record and was categorised into two levels: 1–3 (optimal) and ≥4 (suboptimal) services per conception; (2) time from calving to conception=a continuous variable exported from the DMS as number of days between calving and conception for each cow, where the event was defined as the occurrence of conception after the calving event; (3) calving interval=a continuous variable calculated as the difference in days between the calving date that led to a PTC or FTC and the subsequent calving date for each individual cow, where the event was described as the occurrence of a subsequent calving; and (4) survival on farm=a variable exported from the DMS as the difference between calving date and date of exiting the farm in days. The event was described as the occurrence of a date of exiting the farm. Date of exiting the farm for cows still present on farm at the end of the study period was replaced by December 31, 2014 as a censor date (64 per cent of the cases) for the survival analysis.

Further data management included recoding independent variables used in the statistical models. Two *sire types* were defined (*type 1*—sire from dairy breeds known to have average GL within 280 days, namely Holstein, HF, BF, Jersey, Guernsey; and *type 2*—sire from all beef breeds (Aberdeen Angus, Belgian Blue, Charolais, Hereford, South Devon and Welsh Black) and dairy breeds known to have average GL longer than 280 days, namely Milking Shorthorn, Montbéliarde, Norwegian Red and Swedish Red). The *stage of lactation* at the day of the milk recording was recoded in three levels: early=1–120 days, mid=121–240 days and late lactation=241+ days postpartum.

Statistical analysis

All analyses were performed on the IBM SPSS Statistics V.23 for Windows. Tests for normality were carried out with the Kolmogorov-Smirnov test, and no departures from normality were identified in any of the continuous variables analysed.

Descriptive analysis of continuous variables representing milk production and reproductive performance are reported as mean values with ±sd, and the independent variables *type of calving*, *parity*, *calving year*, *calving month*, *stage of lactation* and *sire type* were reported as absolute and/or relative frequencies.

Linear mixed models were used to assess the effect of type of calving (PTC or FTC) on the outcome variables for milk production and composition (CumMY, MProt, BFat and SCS) in the lactation following a calving event. *Parity* (five levels: 2, 3, 4, 5 and 6+), *calving year* (four levels: 2011–2014), *calving month* (12 levels: January–December), *stage of lactation* (three levels: early, mid and late) and *sire type* (1 and 2) were included as fixed effects likely to affect the outcome variables. *Farm* was included as a random effect in the model to account for the effects due to different farming systems. Results of linear mixed models are reported as model means with ±se.

Generalised linear mixed effect models with binary logistic regression were used to assess the effect of type of calving on two outcome variables: occurrence of clinical mastitis and number of services per conception. The models were adjusted for parity, calving year, calving month, stage of lactation and milk yield as fixed effects with farm as a random effect. Odds ratios (OR) and 95 per cent confidence intervals (CI) for the calving types were reported.

Kaplan-Meier (KM) survival analysis with plots and log-rank tests were used to compare the effect of type of calving on *time from calving to conception*, *calving interval* and *survival on farm*. Results are presented as median survival time with se. Univariable and multivariable Cox regression analyses were carried out to assess the effect of type of calving while adjusting for the potential confounding effects of parity, calving year, calving month, stage of lactation and milk yield. Hazard ratios (HR) and 95 per cent CI for the calving types were presented.

Biologically plausible interactions among the independent variables were assessed in the mixed effects models and Cox regression. Backward elimination selection methods were adopted to eliminate non-significant predictors. Significance was set at $P<0.05$.

RESULTS

Data quality

A response rate of 37 per cent (553/1483) of farms contacted resulted in a positive response rate of 15 per cent (225/1483) as a large number of farms were no longer in production at the time of initial contact, had lost interest after initially agreeing to participate or were not contactable (Fig 1). A total of 194 farm-years (58 per cent) were excluded for presenting over 2 per cent of gestations longer than 295 days, from which 22 farms (7 per cent) had zero good quality farm-years. Only 14 farms (4 per cent) had all four farm-years of good quality data.

Out of the 53 farms included in the final sample, 8 (15.1 per cent) were operating in an all-year-round indoor system with free stalls (silage-based diet), and 45 (84.9 per cent) were operating a pasture-based system in the summer (grass-based diet) combined with free stall in the winter (silage-based diet). Also, 39 farms (73.6 per cent) based their reproduction management in an all-year-round calving system, 7 (13.2 per cent) were calving in block in the autumn, 3 (5.7 per cent) in spring, 2 farms (3.8 per cent) were calving in both spring and autumn, and 2 farms (3.8 per cent) were not using any of these distinct systems.

Descriptive statistics of type of calving, year, month, parity, stage of lactation and sire

Out of the 5759 calvings analysed, 72.7 per cent and 27.3 per cent belonged to the FTC and PTC groups, respectively. This does not represent the true prevalence of PTC in the studied farms due to the exclusion of data records during the process of data screening.

The four years of the study showed a well-balanced representation, with 1304 (22.6 per cent) studied calvings happening in 2011, 1158 (20.1 per cent) in 2012, 1246 (21.6 per cent) in 2013, and 2051 (35.6 per cent) in 2014. Each year of the study observed 20 per cent or more of PTC. The calving months were also well represented, showing frequencies between 5.7 per cent in February and 11.9 per cent in September, and all months presented preterm calvings. The parity levels (2, 3, 4, 5 and 6+) were well represented with a distribution of 31.2, 24.3, 16.5, 12.4 and 15.5 per cent, respectively. Cows in parity 1 were absent from the database due to the use of exclusively milk-recorded animals at the time of breeding,

TABLE 1: Descriptive statistics presented as mean±sd for the outcome variables for milk production and composition parameters in the preterm calving and full-term calving groups (N is the number of valid records for each variable in the study group from a total of 5759 records from 53 farms)

Type of calving		Preterm calving				Full-term calving			
Outcome variables	Missing records	N	Mean±sd	Minimum	Maximum	N	Mean±sd	Minimum	Maximum
Cumulative milk yield (kg)	281	1492	7342±43	150	26 438	3986	7527±42	210	25 342
Average milk protein (%)	281	1492	3.21±0.24	2.38	4.62	3986	3.21±0.25	2.11	4.57
Average butter fat (%)	281	1492	3.94±0.61	1.58	6.62	3986	3.99±0.60	1.83	7.04
Average somatic cell score	494	1432	2.04±0.54	0.90	4.00	3833	2.02±0.55	0.70	3.96

for the calculation of the GL. The stage of lactation had an uneven distribution of 5.8, 18.1 and 76.1 per cent for the early, mid and late lactation groups, respectively, mostly due to the inclusion of the last milk recording in each individual's lactation. The sire types had frequencies of 83 per cent for type 1, with 31 per cent of PTC in this group; and 17 per cent for type 2, with 20 per cent of PTC in this group. Five of the 53 farms in the study did not experience any occurrences of PTC, representing 39 (0.7 per cent) individual cow records.

Association between type of calving and milk yield and composition

Table 1 presents descriptive statistics for the milk production and composition for the PTC and FTC groups. The results of linear mixed modelling (Table 2) showed a significant reduction in the CumMY of 236 kg (P<0.01), increased MProt (P=0.01) and decreased BFat (P=0.02) in the PTC group. No significant difference on the SCS was found between groups. Sire type did not have a significant impact on the outcome variables except for the SCS.

Occurrence of clinical mastitis

Twenty-six out of the 53 farms (49 per cent) had no records of clinical mastitis cases in the database. In the remaining 27 farms with records (51 per cent), out of the 3814 cases used to analyse the occurrence of mastitis, 1187 (31.1 per cent) belonged to the PTC group and 2627 (68.9 per cent) to the FTC group.

The occurrence of clinical mastitis in the lactation was observed in 35 per cent of the PTC individuals and in 30 per cent of FTC individuals. Type of calving did not have an effect in this outcome (Table 3; OR=0.95, P=0.61), but all other fixed variables were significant as expected, namely parity (P<0.01), stage of lactation (P<0.01), calving year (P<0.01) and calving month (P=0.03), where environmental conditions play an important role in the occurrence mastitis, contributing to exposure of cows to infectious environmental pathogens.

Disease and fertility performance

There was an association between calving year (P=0.01) and stage of lactation (P<0.01) and the number of services per conception, where cows were more likely to need fewer services to conceive in 2014 and in the mid-lactation. Parity and calving month showed no significant effect on the estimated means of this variable (P=0.77 and P=0.99, respectively). Type of calving did not show a significant association with this outcome at a 5 per cent level in the multivariable analysis (Table 3; P=0.07).

Fig 2 shows the KM survival curves of 2643 cows that conceived after a PTC or FTC. The estimated median times from calving to conception were 103 (±2.6) and 110 (±1.8) days for the PTC and FTC animals, respectively (P=0.02), indicating that PTC cows were more likely to get in calf sooner than the FTC group. A multivariable Cox regression analysis including parity (P<0.01), calving year (P<0.01), stage of lactation (P<0.01) and milk yield (P<0.01) as confounders did not demonstrate significant difference between the PTC and FTC groups in time to

TABLE 2: Summary of results of the linear mixed models showing the estimated marginal means (±se) reported as the mean response for type of calving group adjusting for potential confounding variables in the model, and significance for the outcome variables for milk production and composition parameters

	Estimated marginal means (±se)		P values					
Outcome variables	Preterm calving	Full-term calving	Type of calving	Parity	Calving year	Calving month	Sire type	Stage of lactation
Cumulative milk yield (kg)	5451 (±207)	5687 (±200)	<0.01	<0.01	<0.01	<0.01	0.08	<0.01
Average milk protein (%)	3.22 (±0.02)	3.20 (±0.02)	0.01	<0.01	<0.01	<0.01	0.15	<0.01
Average butter fat (%)	4.03 (±0.04)	4.07 (±0.04)	0.02	0.17	<0.01	<0.01	–*	<0.01
Average somatic cell score	2.12 (±0.03)	2.13 (±0.03)	0.94	<0.01	<0.01	0.01	<0.01	<0.01

*Sire type (P=0.81) was not included in the multivariable analysis for average butter fat.

TABLE 3: Effects of type of calving on the occurrence of clinical mastitis and number of services per conception adjusting for calving year, calving month, parity and stage of lactation using generalised linear mixed effects models

		Generalised linear mixed model					
Outcome variables	N	Calving year	Calving month	Parity	Stage of lactation	Type of calving	Adjusted OR (95% CI) PTC v FTC
Occurrence of clinical mastitis	3785	P<0.01	0.03	P<0.01	P<0.01	P=0.61	0.95 (0.78 to 1.16)
Number of services per conception	4195	P=0.01	–*	–*	P<0.01	P=0.07	1.17 (0.99 to 1.40)

*Calving month (P=0.99) and parity (P=0.77) were not included in the multivariable analysis for number of services per conception.
CI, confidence interval; FTC, full-term calving; OR, odds ratio; PTC, preterm calving.

conceiving (P=0.13; Table 4). Calving month was not included in the model (P=0.40).

Out of the 1818 animals that had a recorded calving interval, 582 (32 per cent) belonged to the PTC group and 1236 animals (68 per cent) to the FTC group. Overall mean calving interval in this study was 413±79.0 days.

The estimated median times for the calving interval were 388±2.8 days and 395±2.5 days for the PTC and FTC groups, respectively, but this difference was not statistically significant (P=0.29; log-rank test). Multivariable Cox regression analysis also showed no significant difference between the two groups (Table 4; P=0.32), after adjusting for the other potentially confounding variables, with an HR of 1.05 (95 per cent CI: 0.95 to 1.17). Calving month (P=0.33) and parity (P=0.13) were not included in the model.

Survival on farm

Cox regression analysis (Table 4) showed that all variables, including type of calving (P<0.01), had a significant association with survival time on farm. An HR of 0.86 indicates that at any given time the survival rate in the PTC group is 14 per cent higher than the survival rate in the FTC group, after 300 days postpartum.

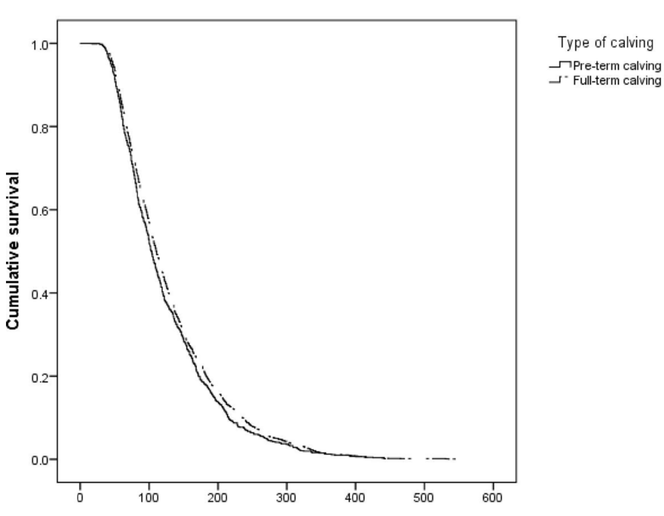

FIG 2: Kaplan-Meier survival analysis of the time from calving to conception for 2782 cows in the preterm calving (n=834) and full-term calving (n=1948) groups.

At the end of the study period, 41 per cent of 5759 animals had exited the farm, 25 per cent (n=588) belonging to the PTC group and 75 per cent (n=1762) to the FTC group. The two groups did not differ significantly in their survival times on farm in the first 300 days postpartum (P=0.99). However, after 300 days of calving, the KM survival curves (Fig 3) show that PTC animals were more likely to stay longer on farm (750±48.9 days) when compared with the FTC animals (529±21.1 days; P<0.01).

DISCUSSION

A 15 per cent positive response rate illustrates the challenges of recruiting farms for large surveys as the one reported in this work. The exclusion of many farm-years and records indicates that data input is often inaccurate, it varies along the years, and quality checks are required when using such databases for careful data analyses. The inclusion criteria defined in the current study were very selective, which reduced the number of individual records available, but these provided the confidence that the service and calving dates used to calculate the GLs were accurate for further analysis.

In the present study, higher frequencies of PTC observed in the end of summer and early autumn are similar to Danish findings,[7] which described summer months as a risk factor for shorter gestations, as a consequence of higher temperatures and dietary changes.

The decreased milk yield in the PTC group is in accordance with previous research that reported a positive correlation between milk yield and GL in Holstein cattle.[8] First calf cows were found to experience more PTC,[3] which could have explained lower yields, but no primiparous was included in this study due to the nature of data collection. The difference in yield was previously explained by an underdevelopment of the mammary gland[23] and shorter dry periods, where cows with a dry period length ranging from 21 to 35 days had a 305-day milk production of 7587 kg, compared with 8436 kg in cows with a dry period longer than 35 days.[24] However, whether the decreased yield is primarily due to genetic control, where low yielders have shorter gestations, or environmental factors, such as dry period length or stressors causing both shorter gestations and low yields,

TABLE 4: Survival analysis of the effects of type of calving on days from calving to conception, calving interval and number of days on the farm based on Kaplan-Meier method, log-rank test and multivariable Cox regression modelling

		Days from calving to conception	Calving interval (days)	Survival on farm (days)
Number of observations included in the analysis		**2643**	**1684**	**5759**
Kaplan-Meier estimated median±se	PTC group	103±2.6	388±2.8	750±48.9
	FTC group	110±1.8	395±2.5	529±21.1
Log-rank test	Type of calving	P=0.02	P=0.29	P<0.01
Multivariable Cox regression	Calving year	P<0.01	P<0.01	P<0.01
	Calving month	–*	–*	P<0.01
	Parity	P<0.01	–*	P<0.01
	Stage of lactation	P<0.01	–*	P<0.01
	Milk yield	P<0.01	P<0.01	P<0.01
	Type of calving	P=0.13	P=0.32	P<0.01
Adjusted HR (95% CI) of PTC v FTC in multivariable Cox regression		1.07 (0.98 to 1.16)	1.05 (0.95 to 1.17)	0.86 (0.78 to 0.94)

*Calving month was not included in the multivariable analysis of days from calving to conception (P=0.40); calving month (P=0.33), parity (P=0.13) and stage of lactation (P=1.00) were not included in the multivariable Cox regression for calving interval.
CI, confidence interval; FTC, full-term calving; HR, hazard ratio; PTC, preterm calving.

is uncertain. The higher percentage of MProt in the PTC group can be explained by the decrease in the milk yield, due to the inverse relationship between these two parameters as a result of a concentration effect of proteins in milk. The percentage of BFat can be affected by several factors, including an inverse relationship with milk yield. However, the PTC presented a significantly lower BFat, indicating that the variation in this parameter was influenced by other factors. These factors may include calving month, as many PTCs occurred in autumn months, which have been associated with lower BFat; and calving year, as a consequence of forage quality. Sire type had no effect

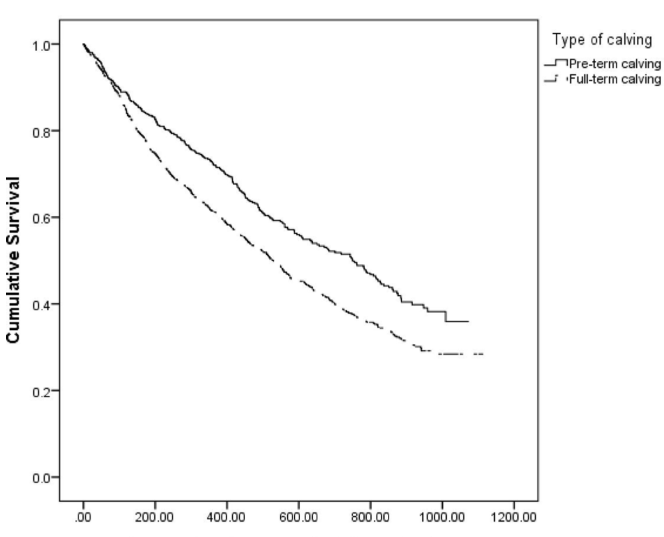

FIG 3: Kaplan-Meier survival analysis of the survival time on farm over 300 days postpartum for 3162 cows in the preterm calving (n=836) and full-term calving (n=2326) groups.

on the production variables, suggesting that the direct genetic effect was not a significant confounding factor on the outcomes of this study.

Under-reporting of clinical mastitis cases may have occurred in this study. Nevertheless, the results are in accordance with the SCS findings reported above, where no significant difference was found between the groups. This indicates that whether a cow has experienced a PTC or an FTC, no association was found with the occurrence of clinical (and subclinical) mastitis in the subsequent lactation.

PTC cows seemed to need fewer services per conception than FTC cows, but this difference was not significant. According to the literature,[10] there is an association between an increased number of inseminations and negative energy balance, which in turn is correlated to higher yields.[12]

The findings indicate that PTC animals experienced shorter times from calving to conception, but that is likely due to reduced milk yield. FTC cows can experience increased negative energy balance due to decreased feed intake, leading to increased time from calving to conception.[10 25] Also, bigger calves have been associated with poorer reproductive performance as a consequence of dystocia[26] and retained fetal membranes,[17] and this is more likely to have occurred in the FTC group, due to a maximal rate of bodyweight gain in the fetus of 352 g per day in the last trimester of gestation.[27]

The overall mean calving interval in this study (413 days) is similar to the national calving interval of 414 days reported recently in GB,[28] but further away from the 426 days reported in a study using national cattle movement records, in beef and dairy cattle.[29] The PTC group had only 5 per cent more animals with a recorded calving interval at any given time in the study, suggesting that PTC cows were getting in calf and having a following calving at a higher frequency than their FTC mates. This finding was not supported by statistical significance but can be aligned with the results presented above, namely the tendency for shorter calving to conception intervals and the number of services per conception, where PTC cows are more likely to present better fertility performances. The reasons for a longer survival on farm could relate to this tendency for better fertility performance, as poor fertility is a major reason for culling in British dairy farms (M. Velasova, A.F. Damaso, B.C. Prakashbabu, J. Gibbons, S. Van Winden, M. Green, J. Guitian, unpublished observations), but also other risk factors, namely udder conformation and teat condition,[30] lameness,[31] and infectious diseases, for example, Johne's disease,[32] all of which were not accounted for in this study.

CONCLUSIONS

This study suggests that PTC occurs in a large proportion of British dairy farms, with an increased frequency in the late summer and early autumn. Cows that experienced a PTC produced less milk in the following lactation and showed a tendency for shorter time from calving to conception. Better fertility performance might have been associated with increased chance of these animals to stay longer on farm.

The study's retrospective nature warrants caution when inferring cause–effect relationships between PTC and the outcomes reported. The analysis did not take into consideration the occurrence of twinning, which has been associated with increased culling rates in British cattle, or previous and following lactation performances of each individual or specific sire traits to account for direct and indirect heritability effects.

This study is an added tool to support decision-making processes on the selection of sires that affect the GL. Also, farmers will be able to better manage the dry period of cows more likely to experience a PTC due to genetic selection of the sire when anticipating an earlier calving. However, it is still unclear which environmental factors can impact on the occurrence of PTC and how much, such as infectious diseases in the herd, dietary changes and husbandry practices. Therefore, the current work suggests further investigation should be carried out to understand if environmental stressors have an impact on the occurrence of these events, so more focus can be put into managing PTC.

Acknowledgements We would like to thank James Hanks from PAN Livestock Services for answering all technical queries on the data management with InterHerd+ and to all the farmers who agreed to participate in the study.

Contributors All authors have revised the work critically for important intellectual content, given their final approval of the version to be published and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Furthermore, the authors have contributed as follows: AFD, substantial contributions to the conception, design and planning of the work, the acquisition, analysis and interpretation of data, and drafting of the work; MV, substantial contributions to the design of the work, and the acquisition and analysis of data; SVW, substantial contributions to the design and planning of the work, and analysis and interpretation of data; YC, substantial contributions to the analysis and interpretation of data for the work; JG, substantial contributions to the design of the work and interpretation of data.

Funding The AHDB Dairy (Division of the Agricultural and Horticultural Development Board) funded the larger study from which the study sample was collected.

Competing interests None declared.

Ethics approval The project was approved by the Clinical Research and Ethical Review Board at the Royal Veterinary College (approval number URN 2013 0097H).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Herd-level data collected from a cross-sectional study are available to the current authors to further study some of the risk factors of preterm calving in British herds. The data are stored in the RVC intranet database.

REFERENCES

1 Andersen H, Plum M. Gestation length and birth weight in cattle and buffaloes: a review. *J Dairy Sci* 1965;48:1224–35.
2 DeFries JC, Touchberry RW, Hays RL. Heritability of the length of the gestation period in dairy cattle. *J Dairy Sci* 1959;42:598–606.
3 Norman HD, Wright JR, Kuhn MT, *et al*. Genetic and environmental factors that affect gestation length in dairy cattle. *J Dairy Sci* 2009;92:2259–69.
4 Nogalski Z, Piwczyński D. Association of length of pregnancy with other reproductive traits in dairy cattle. *Asian-Australas J Anim Sci* 2012;25:22–7.
5 Crews DH. Age of dam and sex of calf adjustments and genetic parameters for gestation length in Charolais cattle. *J Anim Sci* 2006;84:25–31.
6 Day JD, Weaver LD, Franti CE. Twin pregnancy diagnosis in Holstein cows: discriminatory powers and accuracy of diagnosis by transrectal palpation and outcome of twin pregnancies. *Can Vet J* 1995;36:93–7.
7 Hansen M, Misztal I, Lund MS, *et al*. Undesired phenotypic and genetic trend for stillbirth in danish holsteins. *J Dairy Sci* 2004;87:1477–86.
8 Silva HM, Wilcox CJ, Thatcher WW, *et al*. Factors affecting days open, gestation length, and calving interval in Florida dairy cattle. *J Dairy Sci* 1992;75:288–93.
9 Norman HD, Wright JR, Miller RH. Potential consequences of selection to change gestation length on performance of Holstein cows. *J Dairy Sci* 2011;94:1005–10.
10 Collard BL, Boettcher PJ, Dekkers JC, *et al*. Relationships between energy balance and health traits of dairy cattle in early lactation. *J Dairy Sci* 2000;83:2683–90.
11 de Vries MJ, Veerkamp RF. Energy balance of dairy cattle in relation to milk production variables and fertility. *J Dairy Sci* 2000;83:62–9.
12 Harrison RO, Ford SP, Young JW, *et al*. Increased milk production versus reproductive and energy status of high producing dairy cows. *J Dairy Sci* 1990;73:2749–58.
13 Meyer CL, Berger PJ, Koehler KJ. Interactions among factors affecting stillbirths in Holstein cattle in the United States. *J Dairy Sci* 2000;83:2657–63.
14 Bourdon RM, Brinks JS. Genetic, environmental and phenotypic relationships among gestation length, birth weight, growth traits and age at first calving in beef cattle. *J Anim Sci* 1982;55:543–53.
15 Jenkins GM, Amer P, Stachowicz K, *et al*. Phenotypic associations between gestation length and production, fertility, survival, and calf traits. *J Dairy Sci* 2016;99:418–26.

16 Hossein-Zadeh NG, Ardalan M. Evaluation of the potential effects of abortion on the productive performance of Iranian Holstein dairy cows. *Anim Sci J* 2011;82:117–21.
17 Hayes EP, Christley RM, Dobson H. Effects of periparturient events on subsequent culling and fertility in eight UK dairy herds. *Vet Rec* 2012;170:540.1–540.
18 Noakes DE, *et al*. Chapter 3 - Pregnancy and its diagnosis. In: Noakes DE, Timothy JP, England GCW, eds. *Arthur's veterinary reproduction and obstetrics*. 8th edn. Oxford: Saunders WB, 2001b:69–118.
19 Peters AR, Poole DA. Induction of parturition in dairy cows with dexamethasone. *Vet Rec* 1992;131:576–8.
20 Velasova M, Damaso A, Prakashbabu BC, *et al*. Herd-level prevalence of selected endemic infectious diseases of dairy cows in Great Britain. *J Dairy Sci* 2017;100:9215–33.
21 Noakes DE. Chapter 1 - Endogenous and exogenous control of ovarian cyclicity. In: Noakes DE, Timothy JP, England GCW, eds. *Arthur's veterinary reproduction and obstetrics*. 8th edn. Oxford: W.B. Saunders, 2001a:3–53.
22 Ali AKA, Shook GE. An optimum transformation for somatic cell concentration in milk1. *J of dairy science* 1980;63:487–90.
23 Wall EH, Auchtung TL, Dahl GE, *et al*. Exposure to short day photoperiod during the dry period enhances mammary growth in dairy cows. *J Dairy Sci* 2005;88:1994–2003.
24 Steeneveld W, Schukken YH, van Knegsel AT, *et al*. Effect of different dry period lengths on milk production and somatic cell count in subsequent lactations in commercial Dutch dairy herds. *J Dairy Sci* 2013;96:2988–3001.
25 Butler WR, Smith RD. Interrelationships between energy balance and postpartum reproductive function in dairy cattle. *J Dairy Sci* 1989;72:767–83.
26 Mcclintock SB, GILMOUR A, Goddard M. Relationships between calving traits in heifers and mature cows in Australia. *Interbull Bull* 2003:102–6.
27 Prior RL, Laster DB. Development of the bovine fetus. *J Anim Sci* 1979;48:1546–53.
28 NMR. NMR annual production report shows lowest cell counts and calving interval for 12 years in UK dairy herds. 2016 https://www.nmr.co.uk/news/nmr-annual-report-shows-lowest-cell-counts-and-calving-interval-for-12-years-in-uk-dairy-herds (accessed 16 Jan 2017).
29 Gates MC. Evaluating the reproductive performance of British beef and dairy herds using national cattle movement records. *Vet Rec* 2013;173:499.
30 Sawa A, Bogucki M, Krężel-Czopek S, *et al*. Relationship between conformation traits and lifetime production efficiency of cows. *ISRN Vet Sci* 2013;2013:1–4.
31 Archer SC, Green MJ, Huxley JN. Association between milk yield and serial locomotion score assessments in UK dairy cows. *J Dairy Sci* 2010;93:4045–53.
32 Garcia AB, Shalloo L. Invited review: The economic impact and control of paratuberculosis in cattle. *J Dairy Sci* 2015;98:5019–39.