Risk factor analysis for beef calves requiring assisted vaginal delivery in Great Britain

Citation for published version:
Bragg, R, Macrae, A, Lycett, S, Burrough, E, Russell, G & Corbishley, A 2021, 'Risk factor analysis for beef calves requiring assisted vaginal delivery in Great Britain', *Veterinary Record*, vol. 188, no. 2, e8. https://doi.org/10.1002/vetr.8

Digital Object Identifier (DOI):
10.1002/vetr.8

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Publisher's PDF, also known as Version of record

Published In:
Veterinary Record

Received: 21 April 2020 | Revised: 27 July 2020 | Accepted: 27 September 2020

DOI: 10.1002/vetr.8

Vet Record

ORIGINAL RESEARCH

Risk factor analysis for beef calves requiring assisted vaginal delivery in Great Britain

Rachel Bragg[1] | **Alastair Macrae**[1] | **Samantha Lycett**[2] | **Elizabeth Burrough**[1] | **Geraldine Russell**[1] | **Alexander Corbishley**[1]

[1] Royal (Dick) School of Veterinary Studies and the Roslin Institute, University of Edinburgh, Easter Bush Campus, Roslin, Midlothian EH25 9RG, UK

[2] The Roslin Institute, University of Edinburgh, Easter Bush Campus, Roslin, Midlothian EH25 9RG, UK

Correspondence
Rachel Bragg, Royal (Dick) School of Veterinary Studies and the Roslin Institute, University of Edinburgh, Easter Bush Campus, Roslin, Midlothian, EH25 9RG, UK.
Email: Rachel.bragg@ed.ac.uk

Abstract

Background: Dystocia has serious consequences for both mother and offspring. This study therefore aimed to identify risk factors for dystocia in vaginally delivered spring born beef calves in Great Britain (GB).

Methods: Information on calving assistance, calf sex, birthweight, breed, twinning, dam parity and body condition score (BCS) was collected from 1131 calves across 84 GB farms. Variables were modelled against calving assistance as a binary response variable.

Results: Twins (Odds Ratio [OR] = 5.45), Charolais calves (OR = 3.24), calves from primiparous dams (OR = 5.75) and male calves (OR = 1.75) were at significantly increased risk of requiring calving assistance across all models. Calves born to cows classed as thin (BCS < 2.5/5) were identified in the univariate analysis and in one of the multivariate models (OR = 1.92) as having an increased likelihood of dystocia.

Conclusions: Most beef herds have limited scope to manage cows on the basis of fetal gender and number. However, calf breed, dam body condition and management of primiparous dams can be manipulated to reduce the risk of dystocia and improve supervision. Poor body condition is a novel risk factor for dystocia in beef cows and worthy of further investigation.

1 | INTRODUCTION

Dystocia has serious consequences for both the dam and her offspring. In cattle, there is a direct impact on the calf's lifetime production and on the cow's future in the herd. Calves born following a difficult calving have lower production and higher mortality in both the dairy and beef sectors[1] and are less likely to stand and walk in under 3 h of birth.[2] Assistance at calving also has a negative impact on the cow's future fertility,[3–5] which can lead to increased culling and replacement rates.[6]

Risk factors for dystocia can be divided into those of maternal and those of fetal origin.[7] Maternal risk factors can be further subdivided into problems with expulsion, for example uterine inertia or hypocalcaemia, and obstructions, for example an undersized pelvis or uterine torsion. Fetal risk factors can be subdivided into fetal oversize, abnormal presentation and malformations.

The current research evidence on the effects of nutrition during pregnancy on dystocia are conflicting. Previous studies have failed to demonstrate any association between cow body condition score (BCS) and bodyweight on dystocia in mature Holstein-Friesian cows, [8,9] but that performance in terms of fertility and milk yield post-calving in heifers and cows can be negatively affected by increased BCS/weight gain around calving.[6,10–12] Anecdotally, there is a widespread belief that animals with an increased BCS have a higher likelihood of requiring assistance at calving[13,14] and there is at least one study that has demonstrated that a BCS over 3.5 (on a 5-point scale) is a significant predictor of calving assistance in dairy cows.[15] Interestingly, body condition loss towards the end of pregnancy has been associated with higher dystocia rates.[16]

In addition to cow body condition, there is much focus on the impact of dam nutrition on calf birthweight as a risk factor for dystocia. Feeding a higher level of total digestible nutrients during pregnancy has been shown to have no significant impact on the levels of dystocia, despite an increase in calf weight.[17] However, the literature is conflicting, with other work showing that a diet high in crude protein results in a significant increase in both the level of dystocia and size of calves.[18] Heifers fed on a high plane of nutrition have also been shown to have increased calf birth weights. However, the impact on dystocia is inconsistent, with one study reporting heifers on a low plane of nutrition as having an increase in calving problems [8] whereas another study found no difference in level of calving assistance.[19] Calf birthweight can be manipulated experimentally, with reduced birthweight in calves born to mature cows fed restricted rations in the second and third trimester, compared to non-restricted rations or restriction in the second trimester alone,[20] with another study showing that cows on low energy and low crude protein rations for the second trimester had lower calf birthweights.[21] However, neither study mentions the level of calving assistance required. Restricting the access time for silage feeding in Holstein-Friesian cows in the last trimester of pregnancy has been reported to lead to more difficult calvings and stillbirths,[22] while underfed heifers have an increased rate of dystocia, or an increased level of variability in assistance required.[23,24]

With respect to other risk factors, male calves and twinning have been shown to increase the risk of requiring assistance at calving.[3,25] Calves sired by Charolais, Simmental, Limousin and South Devon bulls have also been reported to experience more calving difficulty than Hereford and Jersey sired calves; however, these data are nearly 50 years old and may not reflect current breeds.[3] Other studies have deemed dam breed to be more accountable for variations in calving ease than sire breed.[26] Dam parity is a consistent predictor of calving ease, with younger animals being at higher risk of calving difficulties.[3,25,27–30]

Breeding plans are often implemented on commercial cattle farms, with calving ease estimated breeding values (EBVs) as a main consideration for natural service or artificial insemination (AI) bull selection. Beef calving ease EBVs are composed of two components: maternal calving ease (or calving ease of daughters) and calving ease direct.[31] Calving ease directly predicts the proportion of a sire's offspring that will be born from an unassisted calving.[31] It has been estimated that the genetic components of calving ease make up about 25% of the risk of dystocia, while the other 75% comes from management of the cow.[32]

The objective of this study was to examine the fetal and maternal risk factors for dystocia in vaginally delivered spring born beef suckler calves, with the aim of identifying those risk factors that could be controlled and thus reduced on commercial beef farms in Great Britain.

2 | MATERIALS AND METHODS

All animal work was approved by the R(D)SVS Veterinary Ethical Review Committee (Reference 102-17).

As part of a separate project to assess failure of passive transfer (FPT) in beef calves,[33] a convenience sample of 84 spring calving beef farms from Great Britain (GB) were enrolled in the winter of 2017/18 through their veterinary practices (74 farms) or the Agriculture and Horticulture Development Board (AHDB) strategic farm programme (10 farms). Farms were eligible if herd size and calving pattern meant that 15 calves at 2–5 days old could be blood sampled by their veterinary surgeon at two visits in spring 2018 for the quantification of serum IgG concentration. Standardised sampling kits including weighbands and data collection forms were sent to the farm's own veterinary surgeon, who was responsible for collecting the samples and farm data. In total, data were obtained from 1131 calves and 984 cows.

The following information was collected for each calf that was blood sampled: sex, breed, whether they were a twin or not, ease of calving (4 point scale – 1: No assistance, 2: Easy assistance, 3: Hard pull/calving jack required, 4: Caesarean section), the weight of the calf at sampling (indirectly assessed using heart girth measurement[34] or by use of weigh scales on some farms), the parity of the dam (heifer or cow) and the BCS of the dam (scale 1.0–5.0[35]). Calves were chosen randomly as a convenience sample for the age range required, excluding calves born by Caesarean section. Caesarean sections were excluded as they had already been shown to be an important risk factor for FPT in calves.[36] This dataset therefore provided a unique opportunity to examine the risk factors for calving assistance in commercial suckler herds, where the result was a live, vaginally delivered calf.

Data were initially stored in tabular format. Data analysis and visualisation was performed using R studio[37] and packages 'ggplot2',[38] 'tidyverse',[39] 'reshape2',[40] 'afex',[41] 'lme4',[42] 'ggpubr',[43] 'EnvStats',[44] 'forcats',[45] 'fmsb',[46] 'dplyr'[47] and pROC.[48] Univariate statistical analysis of individual calf level risk factors used relative risk analysis to determine significance for calves with calving assistance. Statistical significance was taken as $p < 0.05$.

In order to eliminate the subjective interpretation of an easy versus a hard assisted calving, calving assistance was converted into a binary explanatory variable of no assistance or assisted calving. Calf breed was recorded, with 32 different breeds classified. A full table of the calves and breed numbers is provided in Supplementary Table 1. As some breeds only had as few as one calf included, the breeds were reclassified into those with at least 50 calves per breed (pure and cross breed) and the other levels combined into an 'Other' category for modelling purposes (Aberdeen Angus – 251 calves, South Devon – 50 calves, Charolais – 160 calves, Limousin – 163 calves, Simmental – 196 calves, Other – 296 calves).

The BCS of the dam was grouped into classes based on industry recommendations, with BCS < 2.5 classed as 'thin', BCS 2.5–3.5 classed as 'ideal' and BCS > 3.5 classed as 'fat'.[15,35] Calf weight was initially assessed as a continuous variable, and then subsequently using a 41-kg threshold value taken from work that described an increased incidence of dystocia above 41 kg.[49] The

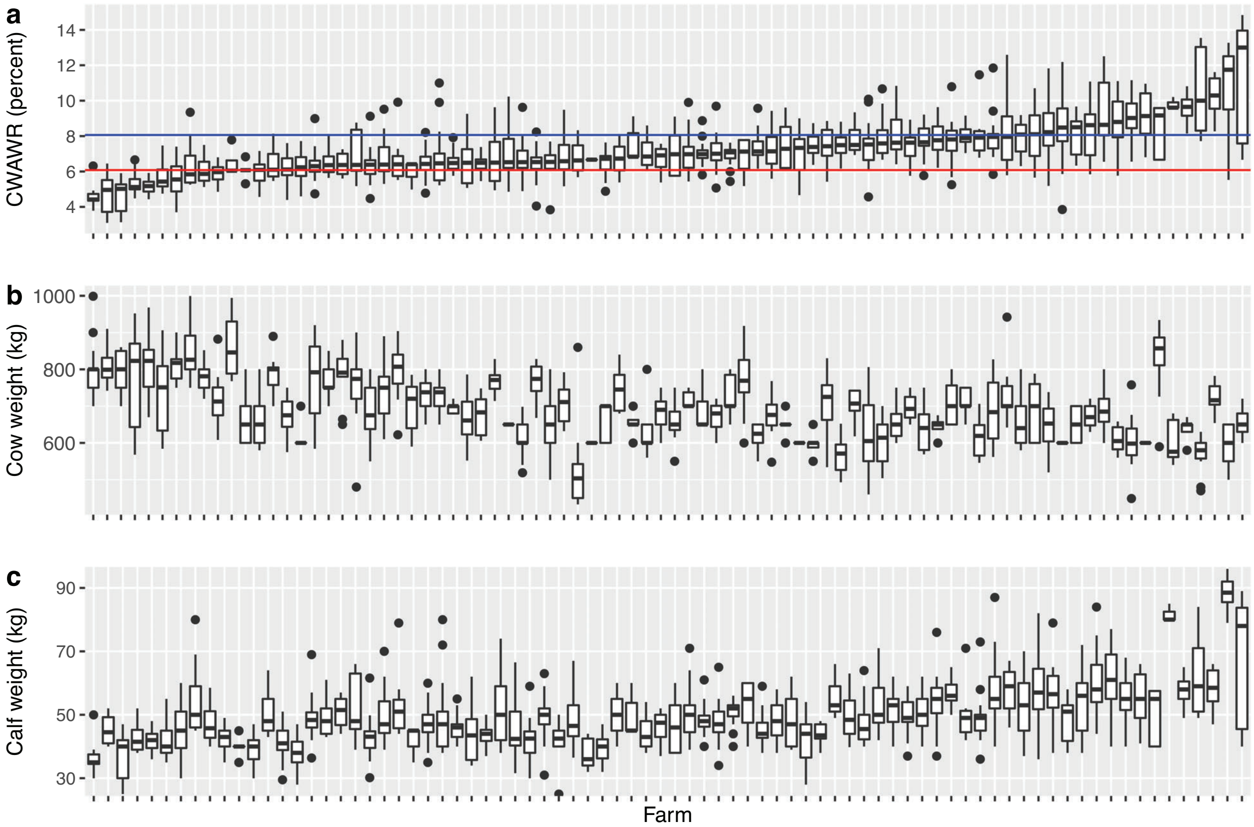

FIGURE 1 Distribution of birth weights of 1131 spring born suckler calves from 84 GB farms in 2018. (a) Calf weight expressed as a proportion of herd average adult cow weight (CWAWR, percent), with lower (red) and upper (blue) quartile thresholds marked. (b) Cow weight (kg) from pregnant adult cows on each farm. (c) Calf birthweight (kg) from calves sampled on each farm

calf weight data were also split into quartiles and interquartile range for further analysis. Calf weight was also analysed taking into account the average size of the cows on farm. Dam weight was taken as the average weight of 12 cows in late pregnancy in each herd measured using heart girth measurement at the start of the study. Calf weight was therefore also calculated as a proportion of the average adult cow weight for each farm, termed the calf weight to adult weight ratio (CWAWR).

Subsequent multivariate analysis used generalized linear mixed models (GLMM) fit by maximum likelihood with Laplace approximation 'glmerMod'. The risk factors above were included as fixed effects and farm as a random effect. Interactions between variables were not considered biologically plausible. Stepwise removal of variables was performed on the basis of the effect their removal had on the model Akaike information criterion (AIC), with a significant effect classed as an increase in AIC of >10. Once a variable had a significant negative effect on the model, the stepwise removal was halted and the final model produced. ROC curve analysis using the package 'pROC'[48] was performed on the CWAWR to try and calculate whether there was an optimum cut-off value that would be predictive of calving assistance. CWAWR was modelled using the inter quartile range (IQR) as an optimum cut-off value could not be determined and when included as a continuous variable, the models failed to converge.

3 | RESULTS

3.1 | Descriptive analysis

One thousand one hundred thirty-one calves were assessed from 84 farms across GB. Mean herd size was 132 cows (range 20–1100). Nine hundred twenty-three calves were reported to have required no assistance at calving (82.2%); 202 calves required assistance at calving (17.8%). Fifteen per cent (140/939) of calves born to multiparous cows required assistance at calving compared to 34% (57/166) of calves born to primiparous heifers. The median dam BCS was 3 (mean 2.9; range 1.5–4.5). The distribution of BCS is provided in Supplementary Table 2. Out of the 1131 calves sampled, there were 45 calves recorded as being twins.

Calf birthweight ranged from 25 to 96 kg (median = 47 kg, mean = 49 kg), measured either indirectly by heart girth measurement[34] or directly with the use of weigh scales. Cow average weight ranged from 528 to 860 kg per farm with the median = 679 kg and mean = 686 kg. CWAWR ranged from 3.1% to 14.8% of average herd cow weight. Figure 1(a) shows the range of CWAWR within and between farms. There was a wide range in CWAWR between farms, indicating a large variation in calf and/or cow weights on individual farms. Figure 1(b) shows the range in cow weights across farms as an indicator of the level of variation expected from the cows, and Figure 1(c) shows the variation in calf weights between farms and

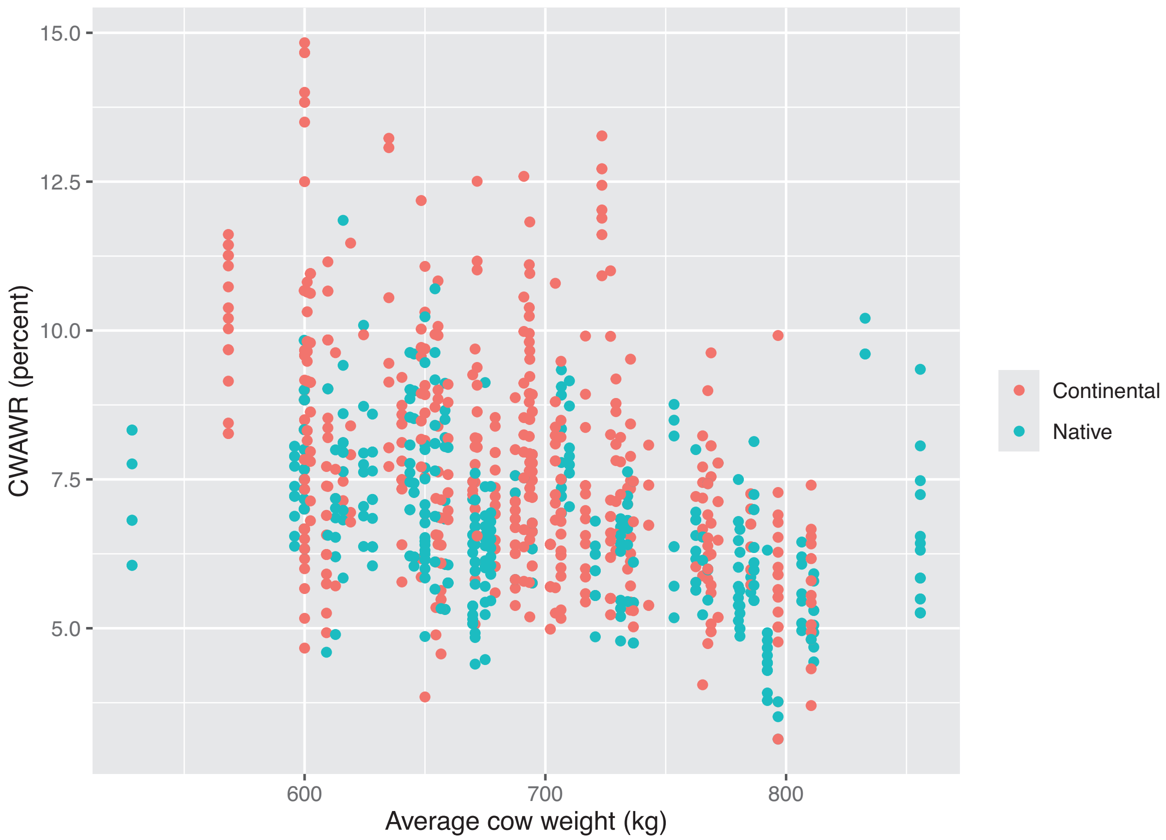

FIGURE 2 Relationship between CWAWR and average cow weight. *R* value = −0.39 and *p*-value = < 0.005. Colour refers to breed of calf falling into the native or continental category with red being continental breeding and blue being native to the UK

on farms. The CWAWR are plotted in order of ascending median value with the upper and lower quartile thresholds marked (lower threshold = 6.09%, upper threshold = 8.06%) (Figure 1(a)). The range in CWAWR between farms is striking, with some herds with cows averaging around 800 kg producing relatively small calves averaging around 40 kg, versus other herds with cows averaging around 600 kg producing calves averaging over 50 kg. Figure 2 shows the correlation between the CWAWR and cow weight. There is a moderate negative correlation (r = −0.39) between the variables, which is significant (p = < 0.005), indicating that larger cows produce proportionally smaller calves.

Exploration of the original dataset of cow BCS (1–5 point scale in ½ point increments) and calving difficulty (4 point scale) showed that there appeared to be a relationship with increasing calving assistance at lower cow BCS (Figure 3(a)). There were 102 (9%) cows classified as thin, 920 (81%) as ideal and 75 (6%) as fat in the study population. It is important to note that there were only four cows (0.4%) that scored over BCS 4.0, hence illustrating that severe obesity at calving is not a major feature of this dataset of spring-calving suckler cows. Due to these small group sizes and potential discrepancies in classification of BCS between farms, it was decided to simplify the data for BCS (three categories: thin, ideal and fat) and calving assistance (binary: yes, no) as seen in Figure 3(b). There was a visual trend for thin cows to have an increased rate of assistance at calving, with 27% (28/102) thin cows requiring assistance compared to 17% (158/920) of cows in ideal body condition, and this was explored further in the subsequent analysis.

Figure 4 demonstrates the relationship between being a twin (a), the dam being a heifer or a cow (b) and calf sex (c), and whether assistance is required at calving or not. Male calves, twins and those born to primiparous dams required greater assistance. Fifteen per cent (140/939) multiparous animals compared to 34% (57/166) primiparous animals required assistance at calving. Seventeen per cent (180/1086) calves that were singleton calves required assistance compared to 38% (17/45) twin calves requiring assistance. Fourteen per cent (75/524) female calves required assistance at calving, compared to 21% (122/592) male calves.

3.2 | Risk factor analysis

Calving assistance was analysed as a binary response variable of assistance being required or not, and the relative risk was calculated for biologically plausible variables that may have an effect on the level of assistance required, with the results summarised in Table 1. Male calves, twins, calves born to primiparous dams, calves born to ‘thin’ cows (BCS < 2.5), Charolais calves, calves that were in the upper quartile of CWAWR and the upper quartile of calf weight (55–96 kg) were all at significantly increased risk of assistance at calving.

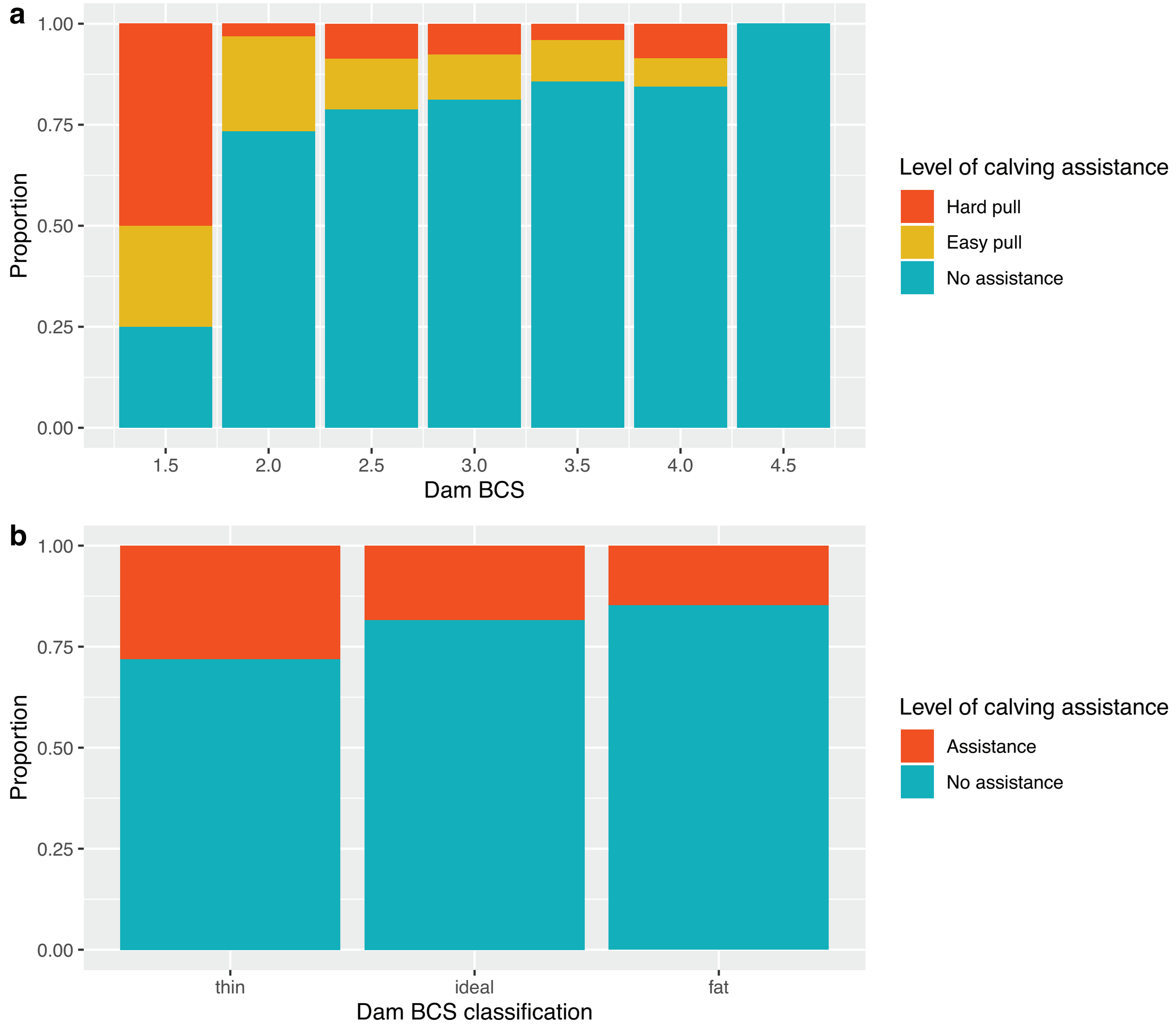

FIGURE 3 (a) The relationship between dam body condition (5 point scale) and the proportion of calves requiring assistance at calving. (B) Simplified BCS data classified into three groups: thin, ideal and fat. Thin cows classed as BCS < 2.5, ideal 2.5–3.5 and fat >3.5 (5 point scale)

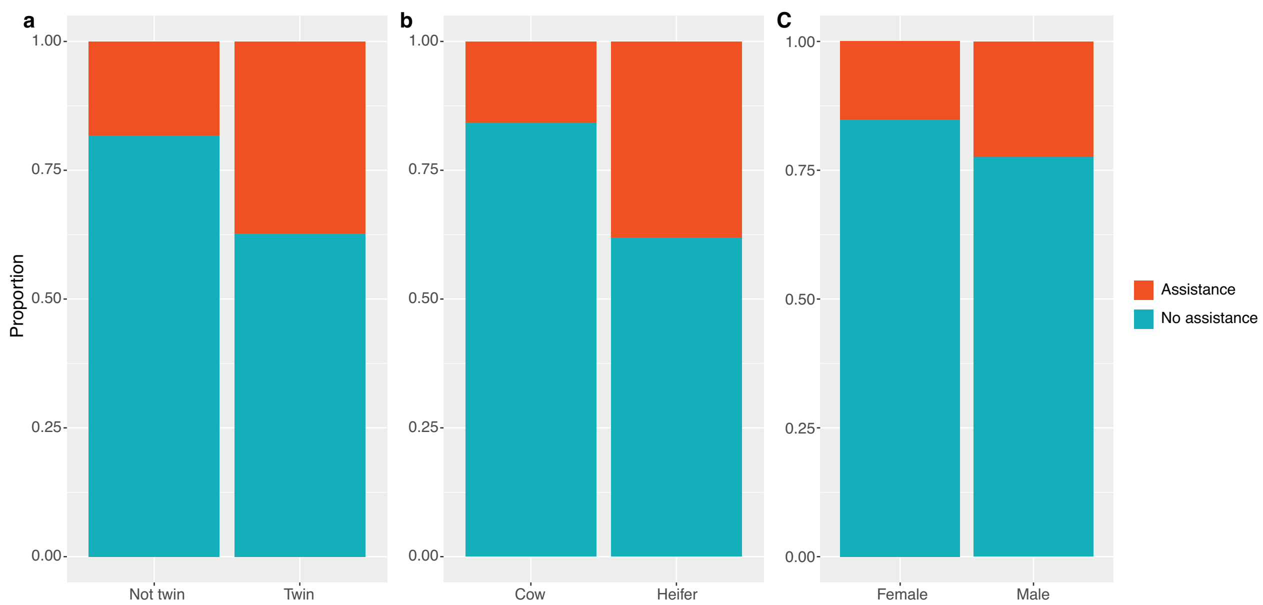

FIGURE 4 Relationship between (A) twin or singleton calf, (B) primiparous or multiparous dam and (C) sex of calf, and whether calving assistance was required

TABLE 1 Relative risk estimates for calving assistance in spring born suckler calves

Variable		*p*-value	Relative risk	95% Confidence Interval
Sex	Male vs. Female	**0.006**	**1.44**	**1.11–1.87**
Twin	Twins vs. Singleton	**<0.005**	**2.28**	**1.53–3.39**
Dam parity	Heifer vs. Cow	**<0.005**	**2.30**	**1.78–2.99**
Dam BCS	Thin vs. Ideal	**0.01**	**1.60**	**1.13–2.26**
	Fat vs. Ideal	0.58	0.85	0.49-1.50
Breed	CH vs. AA	**0.02**	**1.61**	**1.06–2.46**
	LIM vs. AA	0.22	1.32	0.84-2.06
	Other vs. AA	0.25	1.26	0.85-1.87
	SD vs. AA	0.07	1.72	0.96-3.08
	SIM vs. AA	0.48	1.17	0.75-1.82
Calf weight	>41 kg vs. < 41 kg	0.16	1.26	0.91-1.73
CWAWR	Lower quartile vs. IQR	0.23	0.81	0.57-1.14
	Upper quartile vs IQR	**<0.005**	**1.53**	**1.16–2.01**
Calf weight IQR	Lower quartile vs. IQR	0.66	0.93	0.65-1.31
	Upper quartile vs. IQR	**<0.005**	**1.59**	**1.19–2.13**

Values in bold indicate significance at level <0.05.

3.3 | Multivariate analysis

The initial model was built using calf sex, dam heifer/cow, twins yes/no, dam body condition (thin < 2.5, ideal 2.5–3.5, fat > 3.5) and calf breed (CH, AA, Other, LIM, SIM, SD), as these variables were significantly associated with risk of calving assistance in the univariate analysis. Calf weight was also included, as this has been shown in previously published studies to be a biologically plausible risk factor. Initial models were built with calf weight as a continuous variable; however, these models failed to converge. Further analysis using calf weight as a continuous variable to predict dystocia using ROC curve analysis showed limited ability to predict a suitable calf weight threshold (area under the curve: AUC = 0.57), and so weight was converted to a binary variable, using the 41 kg threshold as mentioned previously. Calf weight was also included in quartiles with calves 25–41 kg in the lower quartile, between 41 and 55 kg in the interquartile range and 55–96 kg as the upper quartile.

Calf weight was not significant in the first model as a 41-kg threshold, and so it was removed as part of the stepwise model selection. When calf weight was included as quartiles, the upper quartile became significant and so remained in the model with no stepwise removal of variables performed.

Table 2 summarises these model outputs. Calves that were born to thin cows were at significantly increased risk of requiring assistance at calving (odds ratio [OR] = 1.92), whereas calves born to over conditioned dams were not. Being a twin (OR = 5.05), being born to a heifer (OR = 5.63) and being male (OR = 1.63) all increased the likelihood of a calf requiring assistance at calving. Calves that fell into the upper quartile of calf weight were at significantly increased likelihood of requiring assistance (OR = 2.01). Only one breed category increased the likelihood of a calf requiring assistance at calving relative to the Aberdeen Angus baseline category, the Charolais calves (OR = 2.44). Aberdeen Angus was chosen as the baseline category as it was the majority breed within this dataset, similar to the UK suckler herd, where Aberdeen Angus sits second in breed popularity to the Limousin breed.[50–52]

Calf weight as a binary explanatory variable (threshold at 41 kg) did not have a significant effect on model fit. However when included as quartiles in model 1, the upper quartile (55–95 kg) did have a significant impact on the likelihood of requiring assistance at calving, which is more in line with previous research.[53,54] We went on to explore the relationship of calf weight further as follows. This study was conducted on a large number of farms, where there was significant variation in dam size, with the reported herd average cow weights ranging from 528 to 860 kg. Given this variability, it is perhaps unsurprising that a single weight threshold would not be a reliable explanatory variable for calving assistance. Unfortunately, in the authors' experience, very few GB beef suckler herds have facilities to weigh cattle and therefore accurate data on cow weights was not available for this study. As heart girth measurements were available for 12 cows from each farm, CWAWR was introduced as an explanatory variable. Initially CWAWR was introduced into the model as a continuous factor; however, these models failed to converge. ROC curve analysis was performed to determine whether an ideal threshold value could be selected to convert this proportion into a binary explanatory variable. Figure 5 shows the ROC curve for calving assistance in relation to the CWAWR. The AUC of 0.56 shows that the relationship between CWAWR and calving assistance has limited power to predict

TABLE 2 GLMM multivariable mixed logistic model 1 outputs, with fixed effect variables, number of calves (n), number of calves requiring assistance at calving (nAssist), p-values, and odds ratios (including 95% confidence intervals in brackets)

Model 1: Calving assistance, with calf weight as quartiles.					
Random effect: Farm ID			**Variance:**	**0.81**	
Fixed effects variables:	**Level**	**Number of calves (n)**	**Number of calves assisted (nAssist)**	**p-value**	**OR (95% CI)**
Dam condition	Ideal (BCS 2.5–3.5)	920	158	**reference value (ref)**	**reference value (ref)**
	Fat (BCS > 3.5)	75	11	0.498	1.34 (0.57-3.12)
	Thin (BCS < 2.5)	102	28	**<0.05**	**1.92 (1.04–3.57)**
Twins	No	1086	180	**ref**	**ref**
	Yes	45	17	**<0.001**	**5.05 (2.33–10.95)**
Calf weight	IQR	624	96	**ref**	**ref**
	Lower quartile	267	38	0.375	0.79 (0.47–1.32)
	Upper quartile	237	58	**<0.005**	**2.01 (1.28–3.17)**
Calf breed	Aberdeen Angus	251	35	**ref**	**ref**
	Charolais	160	36	**<0.05**	**2.44 (1.13–5.28)**
	Limousin	163	30	0.561	1.26 (0.57–2.79)
	Other	296	52	0.076	1.84 (0.94–3.59)
	South Devon	50	12	0.240	2.06 (0.62–6.84)
	Simmental	196	32	0.744	1.14 (0.53–2.43)
Dam	Cow	939	140	**ref**	**Ref**
	Heifer	166	57	**<0.001**	**5.63(3.45–9.19)=**
Calf sex	Female	524	75	**ref**	**ref**
	Male	592	122	**<0.05**	**1.63 (1.13–2.35)**

Significance is indicated in bold at the level <0.05.

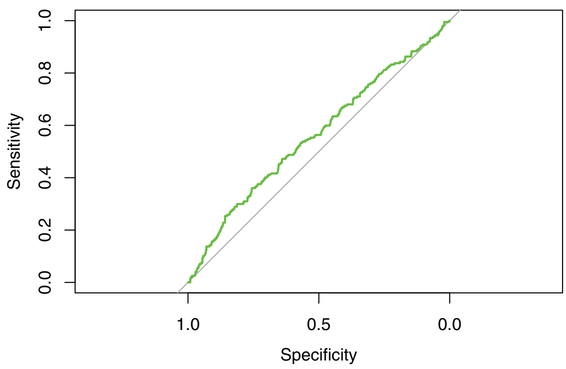

FIGURE 5 ROC curve for calving assistance and CWAWR. Area under the curve (AUC) = 0.56

outcome accurately on its own, and so no ideal threshold value could be determined.

As the ROC curve analysis failed to produce an ideal threshold that could be used as a cut-off value, CWAWR values were divided into those sitting within the interquartile range, the upper quartile and the lower quartile for mixed model analysis. The results for this model (Model 2) are shown in Table 3. Five of the fixed effect variables had significant levels and so were kept in the model. Dam condition became non-significant in this model; however, the model AIC worsened significantly when it was removed, and so the final model contained all six fixed effects. Calves that were twins, were in the upper quartile of CWAWR, were a Charolais breed, born to a heifer or were male, all had an increase in the probability that they required assistance at calving.

4 | DISCUSSION

Economically, assisted calvings have both direct and indirect costs. Famer time is the first direct cost, which is often underestimated by farmers as to the total amount involved. Then there is the possibility of veterinary involvement which will include call out fees, professional time and medicines. Dystocia increases the rate of stillbirths and neonatal mortality in calves and is an important risk factor for FPT,[33] which increases the risk of mortality and infectious disease in early life.[55] There are also additional welfare considerations relating to pain and discomfort for both the cow and calf. Increased time open after calving (an increase from slight to serious difficulty in calving increased days open from 9.2 to 21.5 days[6]), decreased pregnancy rates[9,56] and decreased milk production[9,57] are all reported in dairy cows, while poor conception rates and reduced oestrus expression in beef cows post dystocia have also been reported.[3] Dystocia also results in increased loss of bodyweight and condition in affected Holstein-Friesian cows.[9] One study into the fate of dairy cows after difficult calvings described that 10% of cows that died had "serious difficulties" at calving,[6] whereas another described culling rates in Holstein cows as being increased with an increase in calving assistance score.[56]

This study focused on live calves that were delivered per vaginum. It was striking that nearly one in five calves (17.8%) required assistance at calving, which is likely an underestimate of the true rate of dystocia in GB spring born suckler calves, given that Caesarean

TABLE 3 GLMM multivariable mixed logistic model 2 outputs, with fixed effect variables, number of calves (n), number of calves requiring assistance at calving (nAssist), p-values, and odds ratios (including 95% confidence intervals in brackets)

Model 2: Calving assistance with calf weight as a proportion of herd average cow weight (CWAWR) (IQR used)					
Random effect: Farm ID			**Variance**	**0.83**	
Fixed effect variables:	**Level**	**Number of calves (n)**	**Number of calves assisted (nAssist)**	**p-value**	**OR (95% CI)**
Dam condition	Ideal (BCS 2.5-3.5)	920	158	**reference value (ref)**	**reference value (ref)**
	Fat (BCS > 3.5)	75	11	0.383	1.46 (0.62–3.44)
	Thin (BCS < 2.5)	102	28	0.07	1.78 (0.95–3.33)
Twins	No	1086	180	**ref**	**ref**
	Yes	45	17	**<0.001**	**5.45 (2.49–11.93)**
CWAWR	Interquartile range	568	95	**ref**	**ref**
	Lower quartile	266	37	0.06	0.61 (0.36–1.02)
	Upper Quartile	278	65	**0.022**	**1.69 (1.08–2.65)**
Calf breed	Aberdeen Angus	251	35	**ref**	**ref**
	Charolais	160	36	**0.019**	**2.51 (1.16–5.41)**
	Limousin	163	30	0.596	1.24 (0.56–2.75)
	Other	296	52	0.068	1.87 (0.95–3.67)
	South Devon	50	12	0.196	2.21 (0.66–7.40)
	Simmental	196	32	0.722	1.15 (0.53–2.48)
Dam	Cow	939	140	**ref**	**Ref**
	Heifer	166	57	**<0.001**	**5.75 (3.51–9.41)**
Calf sex	Female	524	75	**ref**	**ref**
	Male	592	122	**0.01**	**1.61 (1.12–2.33)**

Significance is indicated in bold at the level <0.05.

sections and calves that died are not included in this study. Despite these limitations, the risk factors identified in this study are still important in reducing the proportion of calves requiring assistance at delivery and so can still help to inform management practices on farms.

Popular opinion currently points towards overconditioned cows having more problems at calving due to physical obstruction in the pelvic canal,[58] and current industry advice is that spring calving cows should be BCS 3.0 or below at calving,[35] backed up by other research that describes how dairy cattle with greater BCS (>3.5) had greater difficulty at calving.[15] This evidence led to the thresholds used in this paper, with cows in BCS < 2.5 being classed as underweight, BCS 2.5–3.5 as being ideal target condition, and BCS > 3.5 as being overweight.

Interestingly, calves born to "thin" cows were more likely to have suffered from dystocia, identifying a neglected risk factor for dystocia. This was significant in the univariate analysis and model 1 ($p = 0.037$); however, it was not significant when CWAWR was included in model 2 ($p = 0.07$). The significant deterioration in model AIC when body condition was removed suggests that this is still an important predictor of calving assistance and given there were only 102 calves born to thin cows in this study, the statistical significance of this risk factor may have been more consistent in a higher powered study. Thin cows could have higher rates of calving assistance due to a lack of energy around the calving period or other metabolic disturbances. Cows could also be thin because they have lost body condition in the run up to calving, which is a known risk factor for dystocia.[16] There was a big range in the proportion of thin cows per farm, with some farms having up to 73% cows being classed as "thin" body condition. Calves that were born to cows that were classified as "fat" were not at increased risk of dystocia in either of the multivariate models. However, it should be noted that nearly all of the cows classified as "fat" were BCS 4.0 and so there were very few severely obese cows in the study and hence these findings may not be relevant to cows in body condition 4.5 or 5.0. This study looked at body condition across 84 commercially managed farms in England and Scotland, and so it seems that severe obesity was not a major problem in most British suckler cows in the year these results were collected (2018). The other important consideration is that this study only examined the risk factors for dystocia in live calves born vaginally. We therefore cannot exclude 'fat' cows as being at increased risk of caesarean section and/or stillbirth.

Twins have been well documented in the literature as being at higher risk of requiring assistance during delivery, usually as a result of malpresentation or the lack of identification of twins prior to calving leading to prolonged stage 2 labour.[3,9,29] Within this study, twins consistently came out as a significant risk factor in the univariate analysis and both multivariate models.

Calf breed has previously been shown to have an impact on calving difficulty,[3] and this study found that Charolais sired calves were at increased risk of dystocia in both multivariate models, which is similar to previous findings.[3,59] Maternal factors also come into play however, as a Charolais cow carrying a Charolais calf would be much better suited with respect to pelvic size than an Angus cow carrying a Charolais cross calf. Maternal breed was not recorded in this study. Other maternal factors include the age and growth of the dam, with heifers being documented as being at an increased risk of dystocia, which this study agreed with in both modelling scenarios.

The 41-kg calf weight threshold proposed by previous authors as a risk for dystocia was not significant in this study, and we were unable to propose a cut-off using ROC curve analysis. When dividing calf weight into quartiles, calves in the upper quartile (i.e. 55 kg or greater) were at increased risk of dystocia. The CWAWR ratio was developed as a tool to try and combine the calf and adult weight into the analyses. Calf weight weaned as a percentage of adult weight is a widely used metric in the beef sector, with farms that wean a greater proportion of the cow's weight each year considered to be more productive and economically viable.[60] There is a potential risk of this metric selecting for smaller cows that give birth to larger calves, hence increasing the risk of dystocia. The results of this study would suggest that herd managers should aim to keep the CWAWR of their calves under 8% to reduce the risk of dystocia. Monitoring CWAWR within a herd could potentially be used alongside the calf weight weaned as a percentage of adult weight to maximise productivity, whilst minimising dystocia. However, CWAWR is not without drawbacks, as it was calculated in this study from an average weight of pregnant cattle in the herd, not the dam of the calf. This was due to practical constraints on commercial herds; however, future work could calculate CWAWR on an individual dam/calf basis. This may help to define an optimal CWAWR cut-off, particularly in herds where there is significant variation in cow size, rather than the use of the upper quartile in this study. The use of CWAWR on its own would not be recommended, as it has the potential to select for larger cows, which by itself would increase maintenance feeding requirements of the herd and increase pasture damage. Taken together, the results of this study indicate that there is significant variation in adult cow and calf birth weights in GB suckler herds that mean a simple calf birth weight cut-off may not be the most appropriate metric for predicting the likelihood dystocia. A measure of calf birth weight as a proportion of adult cow weight may, however, represent a more useful measure.

5 | CONCLUSIONS

Identification of risk factors for calves requiring calving assistance is of practical value to farmers in helping them to minimise the level of intervention required at calving. Some risk factors identified in this and previous work, such as sex of the calf, cannot be managed in most commercial herds. Other factors such as breed choice are under the direct control of the herd manager.

Twins are consistently identified as at risk of dystocia. If a high proportion of twins are identified by rectal ultrasound examination at 40–70 days gestation,[61] they can be managed separately as a group to make sure nutritional requirements are being met and to improve supervision at calving time to provide assistance earlier. The same is true of primiparous cows.

The finding in this study that thin cows are at increased risk of dystocia has identified a commonly neglected risk factor and highlights the importance of ensuring that body condition is appropriately managed in suckler cows. If thin cows can be identified early in gestation, they can be managed separately to gain condition slowly over the winter. Finally, this study proposes the development of a new metric, CWAWR, which is predictive of calving difficulty due to proportionally larger calf size relative to cow size. The hope would be that this metric can be refined and subsequently used to help inform breeding choices to improve efficient beef production, while trying to limit dystocia and hence the amount of interference required.

ACKNOWLEDGEMENTS

The assistance of the farmers and veterinary surgeons involved in this work is gratefully acknowledged.

FUNDING

English farm work was part-funded by the Agriculture and Horticulture Development Board (AHDB) Beef & Lamb (Grant Number P1711206). Scottish farm work was funded by internal (R(D)SVS) funding.

SL was supported by Roslin Institute Strategic grant funding from the Biotechnology and Biological Sciences Research Council, UK (BBS/E/D/20002173)

ORCID

Rachel Bragg https://orcid.org/0000-0001-5372-0042

REFERENCES

1. Gregory KE, Echternkamp SE, Cundiff LV. Effects of twinning on dystocia, calf survival, calf growth, carcass traits, and cow productivity. J Anim Sci [Internet]. 1996;74(6):1223–33. https://academic.oup.com/jas/article-abstract/74/6/1223/4624766
2. Barrier AC, Ruelle E, Haskell MJ, Dwyer CM. Effect of a difficult calving on the vigour of the calf, the onset of maternal behaviour, and some behavioural indicators of pain in the dam. Prev Vet Med. 2012;103(4):248-56.
3. Laster DB, Glimp HA, Cundiff LV, Gregory KE. Factors affecting dystocia and the effects of dystocia on subsequent reproduction in beef cattle. J Anim Sci. 1973;36(4):695–705.
4. Thompson JR, Pollak EJ, Pelissier CL. Interrelationships of parturition problems, production of subsequent lactation, reproduction, and age at first calving. J Dairy Sci. 1983;66:1119-27.
5. Herring WO. Calving difficulty in beef cattle. Agric MU Guide. 1996;1–6.
6. Mcguirk BJ, Forsyth R, Dobson H. Economic cost of difficult calvings in the United Kingdom dairy herd. Vet Rec [Internet]. 2007;161:685-7. http://veterinaryrecord.bmj.com/

7. Mee JF. Prevalence and risk factors for dystocia in dairy cattle: A review. Vet J. 2008;176(1):93–101.
8. Drennan MJ. Effect of plane of nutrition during late pregnancy on the incidence of calving problems in beef cows and heifers. In: Hoffmann B, Mason I, Schmidt J, editors. Calving problems and early viability of the calf. Dordrecht: Springer Netherlands; 1979. p. 429–43.
9. Berry DP, Lee JM, Macdonald KA, Roche JR. Body condition score and body weight effects on dystocia and stillbirths and consequent effects on postcalving performance. J Dairy Sci. 2007;90(9):4201-11.
10. Buckley F, O'sullivan K, Mee JF, Evans RD, Dillon P. Relationships among milk yield, body condition, cow weight, and reproduction in spring-calved Holstein-Friesians. J Dairy Sci. 2003;86(7):2308-19.
11. Dematawewa CMB, Berger PJ. Effect of Dystocia on yield, fertility, and cow losses and an economic evaluation of dystocia scores for Holsteins. J Dairy Sci. 1997;80(4):754-61.
12. Lombard JE, Garry FB, Tomlinson SM, Garber LP. Impacts of dystocia on health and survival of dairy calves. J Dairy Sci. 2007;90(4):1751-60.
13. Pritchard I, Logan R, Hill G, Caldow G. A guide to improving suckler herd fertility contents [Internet]. QMS. 2017. https://www.qmscotland.co.uk/sites/default/files/qm2879_suckler_herd_a5_brochure_aw_0817_single_0.pdf
14. DEFRA. Condition scoring of beef suckler cows and heifers [Internet]. Action on Animal Health and Welfare. 2001. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69370/pb6491-cattle-scoring-020130.pdf. Accessed January 30, 2020.
15. Fenlon C, O'Grady L, Mee JF, Butler ST, Doherty ML, Dunnion J. A comparison of 4 predictive models of calving assistance and difficulty in dairy heifers and cows. J Dairy Sci. 2017;100(12):9746-58.
16. Gearhart MA, Curtis CR, Erb HN, Smith RD, Sniffen CJ, Chase LE, et al. Relationship of changes in condition score to cow health in Holsteins. J Dairy Sci. 1990;73(11):3132-40.
17. Bellows RA, Short RE. Effects of precalving feed level on birth weight, calving difficulty and subsequent fertility [Internet]. J Anim Sci.1522-8, 1978;46. http://www.journalofanimalscience.org/content/46/6/1522
18. Gunn PJ, Schoonmaker JP, Lemenager RP, Bridges GA. Feeding excess crude protein to gestating and lactating beef heifers: Impact on parturition, milk composition, ovarian function, reproductive efficiency and pre-weaning progeny growth. Livest Sci. 2014;167(1):435-48.
19. Kroker GA, Cummins LJ. The effect of nutritional restriction on hereford heifers in late pregnancy. Aust Vet J. 1979;55:467-74.
20. Freetly HC, Ferrell CL, Jenkins TG. Timing of realimentation of mature cows that were feed-restricted during pregnancy influences calf birth weights and growth rates 1,2. J Anim Sci [Internet]. 2000;78:2790–6. https://academic.oup.com/jas/article-abstract/78/11/2790/4625620
21. Micke GC, Sullivan TM, Soares Magalhaes RJ, Rolls PJ, Norman ST, Perry VEA. Heifer nutrition during early- and mid-pregnancy alters fetal growth trajectory and birth weight. Anim Reprod Sci. 2010;117(1–2):1–10.
22. Gleeson DE, O'Brien B, Mee JF. Effect of restricting silage feeding prepartum on time of calving, dystocia and stillbirth in Holstein-Friesian cows. Ir Vet J [Internet]. 2007;60(11):667. https://irishvetjournal.biomedcentral.com/articles/10.1186/2046-0481-60-11-667
23. Hickson R, Morris S, Kenyon P, Lopez-Villalobos N. Dystocia in beef heifers: A review of genetic and nutritional influences. N Z Vet J [Internet]. 2006;54(6):256-64. https://www.tandfonline.com/doi/full/10.1080/00480169.2006.36708
24. Funnell BJ, Hilton WM. Management and prevention of dystocia. Vol. 32, Veterinary clinics of North America – Food animal practice. W.B. Saunders; 2016. p. 511–22.
25. Bureš D, Bartoň L, Zahrádková R, Teslík V, Fiedlerová M. Calving difficulty as related to body weights and measurements of cows and calves in a herd of Gascon breed. Czech J Anim Sci. 2008;53(5):187-94.
26. Comerford JW, Bertrand JK, Benyshek LL, Johnson MH. Reproductive rates, birth weight, calving ease and 24-h calf survival in a four-breed diallel among Simmental, Limousin, Polled Hereford and Brahman beef cattle. J Anim Sci [Internet]. 1987;64(1):65–76. https://academic.oup.com/jas/article/64/1/65-76/4665776
27. Brinks JS, Olson JE, Carroll EJ. Calving difficulty and its association with subsequent productivity in Herefords. J Anim Sci. 1973;36(1):11-7.
28. Nix JM, Spitzer JC, Grimes LW, Burns GL, Plyler BB. A retrospective analysis of factors contributing to calf mortality and dystocia in beef cattle. Theriogenology. 1998;49(8):1515-23.
29. Echternkamp SE, Gregory KE. Effects of twinning on gestation length, retained placenta, and dystocia. J Anim Sci. 1999;77(1):39–47.
30. Berger PJ, Cubas AC, Koehler KJ, Healey MH. Factors affecting dystocia and early calf mortality in Angus cows and heifers. J Anim Sci. 1992;70(6):1775-86.
31. AHDB. Choosing bulls for better returns [Internet]. 2019 [cited 11 Dec 2019].https://projectblue.blob.core.windows.net/media/Default/Beef&Lamb/ChoosingBullsBR_190813_WEB.pdf. Accessed December 11, 2019.
32. QMS. A Guide to Bull Selection and Management [Internet]. 2016 [cited 3 Apr 2020].https://www.qmscotland.co.uk/sites/default/files/qm2824_bull_selection_management_a5_reprint_aw_0517_issuu_0.pdf. Accessed April 03, 2020.
33. Bragg R, Macrae A, Lycett S, Burrough E, Russell G, Corbishley A. Prevalence of and risk factors associated with failure of passive transfer in spring born beef suckler calves in Great Britain. Prev Vet Med.105059, 2020;
34. Heinrichs AJ, Rogers GW, Cooper JB. Predicting body weight and wither height in Holstein Heifers using body measurements. J Dairy Sci. 1992;75:3576-81.
35. AHDB. Better returns from body condition scoring (BCS) beef cows and heifers [Internet]. 2001 [cited 2019 14 Nov 2019].https://beefandlamb.ahdb.org.uk/wp-content/uploads/2013/06/Better-returns-from-body-condition-scoring.pdf. Accessed November 14, 2019.
36. Odde KC. Survival of the neonatal calf. Vet Clin North Am Food Anim Pract [Internet]. 1988;4(3):501-8. https://www.sciencedirect.com/science/article/pii/S0749072015310276?via%3Dihub
37. RStudioTeam. RStudio: Integrated development for R [Internet]. Boston, MA RStudioTeam; 2018. http://www.rstudio.com/.
38. Wickham H. ggplot2: Elegant graphics for data analysis [Internet]. 2016. https://ggplot2.tidyverse.org
39. Wickham H. tidyverse: Easily install and load the "Tidyverse" [Internet]. 2017. https://cran.r-project.org/package=tidyverse
40. Wickham H. Reshaping data with the {reshape} package. J Stat Softw [Internet]. 2007;21(12):1–20. http://www.jstatsoft.org/v21/i12/
41. Singmann H, Bolker B, Westfall J, Aust F, Ben-Shachar MS. afex: Analysis of factorial experiments [Internet]. 2019. https://github.com/singmann/afex
42. Bates D, Maechler M, Bolker B, Walker S. Fitting linear mixed-effects models using {lme4}. J Stat Softw. 2015;67(1):1–48.
43. Kassambara A. ggpubr: "ggplot2" based publication ready plots [Internet]. 2019. https://cran.r-project.org/package=ggpubr
44. Millard S. _EnvStats: An R Package for environmental statistics_ [Internet]. New York: Springer; 2013. www.springer.com
45. Wickham H. forcats: Tools for working with categorical variables (factors) [Internet]. 2019. https://cran.r-project.org/package=forcats
46. Nakazawa M. fmsb: Functions for medical statistics book with some demographic data [Internet]. 2019. https://cran.r-project.org/package=fmsb
47. Wickham H, François R, Henry L, Müller K. dplyr: A grammar of data manipulation [Internet]. 2019. https://cran.r-project.org/package=dplyr
48. Robin X, Turck N, Hainard A, Tiberti N, Lisacek F, Sanchez, Jean-Charles, Müller M. pROC: An open-source package for R and S+ to analyze and compare ROC curves [Internet]. 2011. p. 77. http://www.biomedcentral.com/1471-2105/12/77

49. Breedplan. Understanding birth weight EBVs [Internet]. 2015 [cited 2 Dec 2019].http://breedplan.une.edu.au/tips/Understanding Birth Wt EBVs.pdf. Accessed December 02, 2019.
50. NFU. Great British beef week. 2020.
51. FarmingUKteam. Aberdeen Angus set to be UK's most popular beef breed [Internet]. Farming UK. 2019. https://www.farminguk.com/news/aberdeen-angus-set-to-be-uk-s-most-popular-beef-breed_53333.html. Accessed December 04, 2020.
52. Condon J. Weekly genetics review: Which breed dominates beef production in the United Kingdom? [Internet]. Beef Central. 2017. https://www.beefcentral.com/genetics/weekly-genetics-review-which-breed-dominates-beef-production-in-the-united-kingdom/#:~:text=The French Limousin breed is, for the past 20 years.&text = The British Limousin Cattle Society,beef cattle are Limousin-influenced. Accessed December 04, 2020.
53. Belcher DR, Frahm RR. Factors affecting calving difficulty and the influence of pelvic measurements on calving difficulty in percentage Limousin heifers. Anim Sci Res Rep. 1979; 136–44.
54. Bellows RA, Short RE, Anderson DC, Knapp BW, Pahnish OF. Cause and effect relationships associated with calving difficulty and calf birth weight. J Anim Sci. 1971;33(2):407-15.
55. Murray CF, Leslie KE. Newborn calf vitality: Risk factors, characteristics, assessment, resulting outcomes and strategies for improvement. Vet J [Internet]. 2013;198:322-8. https://doi.org/10.1016/j.tvjl.2013.06.007
56. Ghavi Hossein-Zadeh N. Effect of dystocia on subsequent reproductive performance and functional longevity in Holstein cows. J Anim Physiol Anim Nutr (Berl). 2016;100(5):860-7.
57. Eaglen SA, Woolliams JA, Coffey M, Wall E. Effect of calving ease on the subsequent performance of cow and calf in UK Holstein-Friesian cattle. Adv Anim Biosci. 2010;1(1):164.
58. Chase C, Lutz K, McKenzie E, Tibary A. Dystocia - Bovine. In: Blackwells five-minute veterinary consult: Ruminant [Internet]. Second. John Wiley & Sons, Inc; 2017 [cited 17 Mar 2020]. p. 300–1. https://books.google.co.uk/books?id=QEkzDwAAQBAJ&pg=PA300&lpg=PA300&dq=pelvic+obstruction+due+to+obesity+cattle&source=bl&ots=rOkBv28sGv&sig=ACfU3U3q6k45qxCou4oxfSipZzzHtbtK1Q&hl=en&sa=X&ved=2ahUKEwik8KC88qHoAhXGShUIHcHOB18Q6AEwDHoECAoQAQ#v=onepage&q=pelv. Accessed March 17, 2020.
59. Mee JF, Berry DP, Cromie AR. Risk factors for calving assistance and dystocia in pasture-based Holstein-Friesian heifers and cows in Ireland. Vet J. 2011;187(2):189-94.
60. AHDB. Calf weight output per cow calculator [Internet]. Better Returns Programme. 2017. http://beefandlamb.ahdb.org.uk/wp-content/uploads/2017/09/Calf-weight-output-per-cow-calculator.xlsx. Accessed March 30, 2020.
61. IMV. Identification of twins in cows | IMV imaging [Internet]. 2020 [cited 30 Jan 2020]. https://www.imv-imaging.co.uk/veterinary-learning/farm-animal-learning/reproductive-tract/identification-of-twins-in-cows/. Accessed January 30, 2020.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Bragg R, Macrae A, Lycett S, Burrough E, Russell G, Corbishley A. Risk factor analysis for beef calves requiring assisted vaginal delivery in Great Britain. *Vet Rec.* 2021;e6. https://doi.org/10.1002/vetr.8