Paper

Assessing the effects of weekly preweaning health scores on dairy calf mortality and productivity parameters: cohort study

Sophie Anne Mahendran, Richard Booth, Lies Beekhuis, Al Manning, Tania Blackmore, Arne Vanhoudt, Nick Bell

A longitudinal cohort study was conducted to follow the health of 787 calves from one UK dairy farm over a two-and-a-half-year period. Weekly health scores were gathered using a modified version of the Wisconsin Calf Scoring system (which did not record ear position) until calves were eight weeks of age, combined with data on colostral passive transfer, mortality, age at first conception and 305-day milk yield. High morbidity levels were detected, with 87 per cent of calves experiencing at least one clinically significant event (diarrhoea, pyrexia, pneumonia, nasal or ocular discharge, navel ill or joint ill). High rectal temperature, diarrhoea and a cough were the most prevalent findings. The effect of total protein levels was significantly associated with the development of pyrexia as a preweaning calf (P<0.01), but no other clinical health scores. The majority of moribund calves had just one clinically severe clinical sign detected at each of the weekly recordings. The overall mortality rate was 21.5 per cent up to 14 months of age, with 12.7 per cent of calves dying during the preweaning period. However, most calves that died were not recorded as having experienced a severe clinical sign in the time between birth and death, indicating a limitation in weekly calf scoring in detecting acute disease leading to death. Therefore, more frequent calf scoring or use of technology for continuous calf monitoring on farms is required to reduce mortality on farms with high disease incidence rates.

Introduction

Early identification of disease in calves is important to ensure good welfare, and because their health status can affect subsequent growth and productivity.[1] Clinical scoring systems in calves have been proposed as an approach to systematic screening for early disease to improve calf health and survival.[2 3] The most prevalent and economically important calf diseases are diarrhoea[4] and respiratory disease[5] which form major components of calf scoring approaches. Detecting disease like calf pneumonia and grading its severity is challenging.[6–8] One study found that stock people detected just 56 per cent of clinical pneumonia cases.[9] Furthermore, agreement between veterinarians for identifying clinical illness in calves has also been reported as poor.[6] Successful treatment of diseased calves, regardless of aetiology, is likely to be determined by the speed of disease detection and treatment, although evidence is sparse on this subject. While the rationale for regular calf scoring is clear, there are few studies evaluating its performance and relationship with calf health parameters.

Disease in preweaned calves has a negative influence on performance later in life.[10] Production of replacement dairy heifers can account for 20 per cent of farm expenses[11] with losses due to disease and death representing a major source of inefficiency.[12] The aim of this study was to investigate whether detection and treatment of disease through the use of a modified Wisconsin calf disease scoring system decreased the impact of disease on future performance as assessed through mortality rates, age at conception and 305-day milk yield. It is hypothesised that preweaned calves with poor clinical scores will perform less well, and have higher mortality rates than their 'healthier' counterparts.

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Materials and methods

Study period and farm management

A longitudinal cohort study was conducted on a 360-cow dairy farm in Dorset, UK, from August 2011 through December 2015. The average 305-day yield was 9434 litres, with cows housed in deep sand cubicles and fed a total mixed ration during the winter. In summer, cows were on pasture grazing grass and had a buffer feed. Cows were milked twice daily. All youngstock were homebred during the study period. Newborn calves were separated from their dam as soon as possible after birth with a maximum interval of 12 hours between birth and separation.

Calves remained at the main dairy farm during their first 24 hours of life to receive two litres of first milked colostrum with-

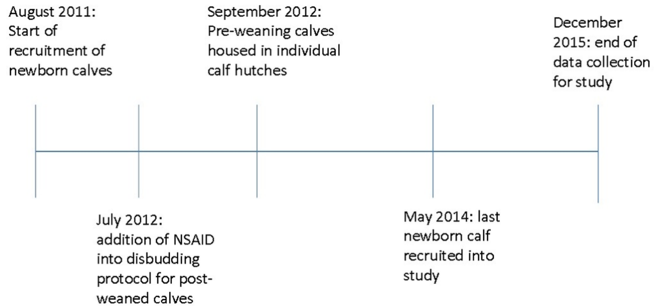

FIG 1: Timeline representation of the management changes that occurred on the farm during the study period.

in six hours of birth from their own dam, fed by bottle. Calves that failed to suckle their colostrum from the bottle were fed with an oesophageal tube. Colostrum collected at the following two milkings of their dams was also fed to the respective calves by bottle. Before September 2012, calves were then transported to a calf rearing site located 4 km from the main dairy farm. This unit only contained youngstock bred on the study farm. Here, the heifer calves were housed in individual pens on straw during their first week of life and thereafter they were grouped in pens of eight and bedded on straw until weaning. During this time, calves were fed twice daily with milk replacer (Advanced Superstart, Advance Sourcing, UK) at 600 g/day mixed in four litres of water through a teat. Weaning took place at eight weeks of age, and was achieved by decreasing milk feeding to once a day for a week, and then withdrawing the milk feed entirely.

From September 2012 onwards, preweaning calves were housed in individual calf hutches (Calf-Tel Deluxe model, USA) after the same initial colostrum management protocol. These hutches were located at the main dairy, placed on compacted rubble flooring. The hutches were bedded with straw daily, and calves had free access to concentrates and water. The hutches were cleaned using a pressure washer and disinfectant (Virkon, Antec International, UK) prior to a newborn calf entering a vacated hutch. The bedding was removed from the ground location of the hutch, and the area was left to dry before a hutch was resited on the same location. The feeding and weaning protocols remained the same.

Calves were disbudded with a hot iron between 8 and 10 weeks of age (postweaning) following lidocaine local anaesthesia (Lidocaine, Norbrook, UK). Calves disbudded after July 2012 received additional treatment with the NSAID meloxicam (0.5 mg/kg; Metacam, Boehringer Ingelheim). The timeline of management changes during the study period is depicted in Fig 1.

After weaning, regardless of location, all calves were housed in large groups of approximately 40–60 animals in straw yards at the calf rearing site located 4 km from the main dairy farm. Once the Holstein-Friesian (HF) replacement dairy heifers reached a body weight of approximately 360 kg, they were eligible for their first insemination. The breeding policy meant that heifers received up to three artificial inseminations with HF semen and were then placed into a group pen with an Aberdeen Angus beef bull to be covered by natural service. Three weeks before their expected calving date the heifers were moved to a group calving pen bedded with straw. This pen contained a mixture of approximately 10–14 cows and heifers. After their first calving, the heifers were housed in deep sand bedded cubicles in a separate primiparous group. Calves that were beef breeds and male HF animals were all designated beef animals, and remained at the calf rearing site until approximately 14 months of age when they were sold.

Data collection and analysis

The farm was visited once a week by a member of Royal Veterinary College (RVC) staff and final year veterinary students. For each calf born on the farm, information was recorded including date of birth, sex and breed. During each weekly visit, every preweaning calf (up to eight weeks old) present was examined using a modified calf scoring system based on that described by[13] (table 1). Consequently, each calf in the study had up to eight assessments prior to weaning, recorded on a weekly basis.

The calf scoring assessment criteria used were modified from that originally published by,[13] with removal of the assessment of ear position. In piloting the scoring system, the main cause of altered ear position on this farm was found to be ear tag placement, rather than disease such as mycoplasma infections encountered elsewhere. Therefore, this component of the score was removed to avoid confounding the study.

To simplify statistical analysis, the calf scores were dichotomised retrospectively using accepted clinical thresholds. For rectal temperature, calves having received a score of 0, 1 or 2 were represented as 0 (normal clinical score), and calves that had received a score of 3 were represented by 1 (abnormal clinical score), which is in agreement with pyrexia thresholds used by other studies.[14] For cough, nasal and ocular discharge and faecal score, calves having received a score of either 0 or 1 were represented with a 0, and calves that had received a score of 2 or 3 were represented by a 1. For both joint ill and navel ill, score 0 represents normal clinical score (absence of the disease) and 1 abnormal clinical score (presence of the disease).

Table 1: A description of the modified calf scoring point allocation system for assessing calf health, adapted from the University of Wisconsin-Madison Calf Health Scoring system [13]

	Clinical scores			
Variable	0	1	2	3
Rectal temperature (°C)	37.8–38.2	38.3–38.8	38.9–39.4	≥39.5
Cough	None	Induced single	Induced repeated or occasional spontaneous	Repeated spontaneous
Nasal discharge	Normal serous	Small amount of unilateral, cloudy mucus	Bilateral, cloudy or excessive mucus	Copious bilateral, mucopurulent nasal discharge
Ocular discharge	Normal	Mild ocular discharge	Bilateral purulent ocular discharge	
Joint ill	No clinical signs of inflammation in any of the joints	Presence of one or more clinical sign(s) of inflammation in any of the joints		
Navel ill	No clinical signs of inflammation of the umbilicus	Presence of one or more clinical sign(s) of inflammation of the umbilicus		
Faecal score	Normal consistency, no blood, fibrin or pseudomembrane present	Semiformed, pasty but no blood, fibrin or pseudomembrane present	Loose but sits on top of bedding ± presence of blood, fibrin discharge or pseudomembranes	Watery, sifts through bedding ± presence of blood, fibrin discharge or pseudomembranes

Ear position was removed from the original scoring system (http://www.vetmed.wisc.edu/dms/fapm/fapmtools/calves.htm).

Treatment protocols

Throughout the study period, calves with disease detected at calf scoring (using the dichotomised scores) underwent a full veterinary clinical examination and were treated on the day using a standardised, predetermined treatment protocol. Calves detected with a rectal temperature score of ≥39.5°C and no other clinical scores, or with a faecal score of 1 were treated with the NSAID meloxicam (0.5 mg/kg; Metacam, Boehringer Ingelheim). Calves with clinical signs of pneumonia, which included a cough, nasal discharge or ocular discharge score of 1, were treated with a combination therapy of florfenicol at 40 mg/kg and flunixin meglumine at 2.32 mg/kg (Resflor, MSD Animal Health) as a first treatment, and with the antibiotic tulathromycin (2.5 mg/kg; Draxxin, Zoetis) for calves that showed clinical signs seven days later (at the next calf visit). Calves with abnormal clinical scores for navel ill or joint ill were treated with a long acting dose of oxytetracycline (20 mg/kg; Engemycin LA, MSD Animal Health) and meloxicam (0.5 mg/kg; Metacam, Boehringer Ingelheim). No additional treatments were given to calves outside of the weekly visits.

Passive transfer of immunity

The level of passive transfer of maternal antibodies through colostrum ingestion was assessed by determining the level of total protein in serum. A blood sample from the jugular vein of calves aged between one and seven days old was collected in a plain tube. Calves were only sampled if deemed to be free from clinical disease (following scoring) and with a normal hydration status as assessed through the use of a skin tent and the degree of enophthalmos.[15] Serum was separated off using centrifugation at 9000 g for five minutes. A visual handheld refractometer was then used to assess the level of total proteins in the serum. A failure of adequate passive transfer (FPT) was defined as a total protein level of less than 5.2 g/dl in a clinically hydrated calf.[16]

Sex, breed, age at first conception, age at first calving and 305-day lactation yield were captured for the animals in the study for the period August 2013 until May 2015. The 305-day milk yield data were obtained through monthly milk recordings conducted by a single company (National Milk Records, Chippenham, UK). Fertility data were recorded by the herd manager using on-farm software program (Interherd, Pan Livestock, Reading, UK).

Statistical model construction

Descriptive and subsequent multilevel statistical analysis was conducted using SPSS (SPSS V.21; Lead Technologies 2012).[17] Due to the different categories of calves used in the statistical analysis, different groups of calves were eligible for contribution to different statistical analyses. Detailed information on the number and types of calves used is presented in Fig 2.

Associations between a calf's total protein level (an indicator of passive transfer of immunity) and the development of clinical signs (diarrhoea, rectal temperature, cough, navel ill, joint ill, ocular discharge, nasal discharge) were analysed using logistic regression, with the covariates of sex and whether it was a beef animal included in the analysis. A receiver operating characteristic (ROC) analysis was then conducted for any clinical sign that was significantly associated with the total protein level to determine an appropriate cut-off value for predicting development of that clinical sign.

Associations between the development of clinical signs (the outcome) and having failure of passive transfer, being a heifer calf and being a beef crossbreed were analysed using logistic regression.

Mortality in the preweaning and postweaning periods were analysed separately. Associations between preweaning death and the development of clinical signs detected at weekly calf scoring (one to eight scores depending on week of death) were assessed using time-dependent Cox regression analysis. The denominator group consisted of calves that either died preweaning or had a complete set of eight calf scores recorded, with other calf records excluded. The death of calves postweaning until the age of 14 months (as this is when beef animals left the farm) was assessed through the use of Cox regression analysis. The denominator group excluded calves that died preweaning and those that did not have a complete set of eight calf scores recorded to remove the confounding effect of missing data.

To assess the association of the measured calf health factors (failure of passive transfer, diarrhoea, coughing, raised rectal temperature, nasal discharge and ocular discharge) with production in the first lactation (the 305-day milk yield and age at first conception), multivariable linear regression models were used, with backwards elimination of non-significant variables to check for correlated health scores. The denominator group was HF dairy heifers with ≥4 calf scores (to ensure a large sample size), which conceived and then survived up to 305 days of their first lactation.

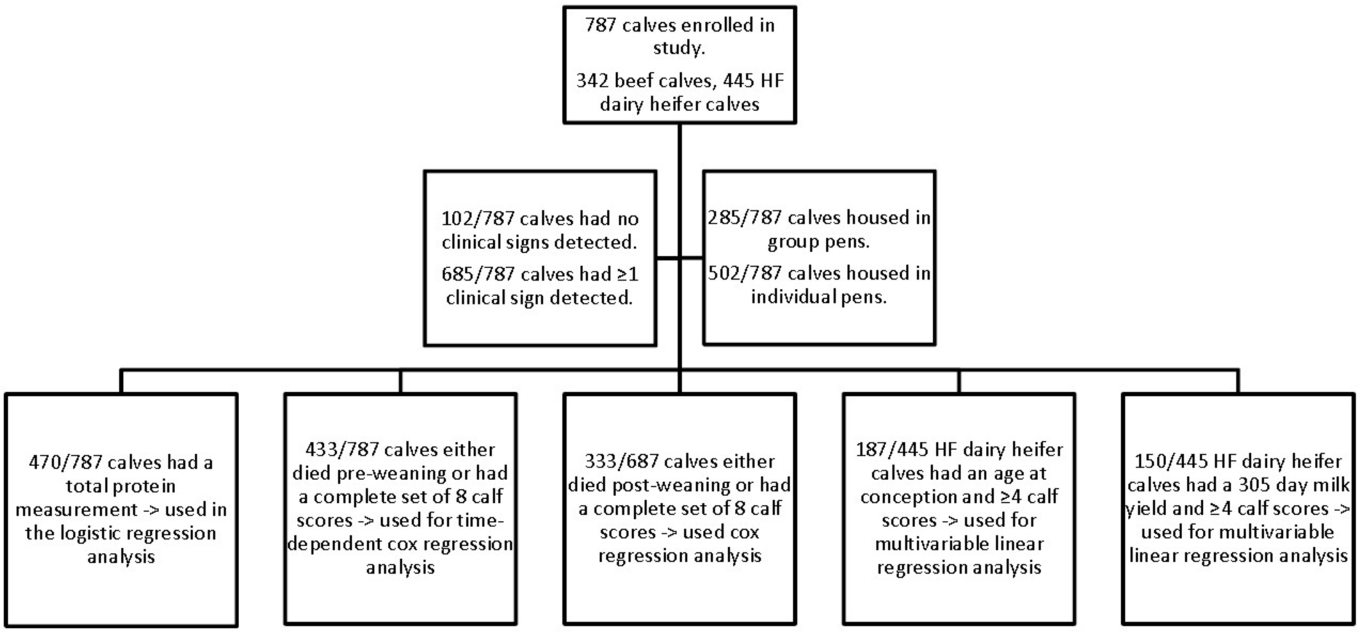

FIG 2: Sample size description of the calves enrolled into the cohort study, with a detailed breakdown of the number of eligible animals, used for each statistical analysis. HF, Holstein-Friesian.

Table 2: The percentage of calves (with se) that had abnormal clinical scores as preweaning animals. The denominator population was the 685 calves that experienced ≥1 abnormal clinical sign during the preweaning period

Type of calf	% Died (se)	% Failure of passive transfer (se)	% Navel ill (se)	% Joint ill (se)	% Diarrhoea (se)	% Pyrexia (se)	% Cough (se)	% Nasal discharge (se)	% Ocular discharge (se)
Beef animal n=342	19.9 (0.02)	33.1 (0.03)	10.3 (0.02)	1.8 (0.01)	46.9 (0.02)	26.8 (0.02)	36.2 (0.02)	12.4 (0.02)	23.8 (0.02)
Dairy heifer n=445	19.0 (0.02)	30.2 (0.03)	9.4 (0.02)	1.2 (0.01)	57.6 (0.03)	33.0 (0.03)	40.1 (0.03)	10.5 (0.02)	17.3 (0.02)

Type I error rate was set at 5 per cent. Post hoc power calculations were conducted to determine the power of the statistical analysis. This study was approved by the RVC Ethical Review Board, reference M2016 0077.

Results

Data from a total of 787 calves were analysed in the longitudinal study. These calves were born between August 2011 and May 2014, resulting in a total of 4738 individual preweaning health scores, with each calf examined an average of six times (range one to eight). Of these calves, 342 were beef animals (43 per cent) and 445 were female HF replacement dairy calves (57 per cent). During the study, a total of 285 calves (36 per cent) were kept in group pens as preweaning calves, with the remaining 502 calves (64 per cent) housed in individual calf hutches.

Of the 787 calves in the study, 102 (13 per cent) survived without having any abnormal clinical scores recorded during the preweaning period. The remaining 87 per cent of calves experienced at least one abnormal clinical score during the preweaning period (table 2), with the predominant scores being for diarrhoea, cough and pyrexia.

The number of calves experiencing multiple severe clinical scores at each individual calf scoring session was evaluated (table 3), with low numbers of calves having multiple severe clinical signs occurring concurrently. The number of recordings with concurrent pyrexia and ocular discharge outweighed the other recordings with 6.96 per cent, compared with 1.90 per cent or less for all other scores, demonstrating that combinations of severe clinical signs occurred infrequently. There was no significant difference in the odds of either a male or female calf developing any of the clinical signs; however, the HF dairy calves had 0.44 lower odds of developing diarrhoea than the beef crossbred calves ($P=0.02$) (table 4).

Total protein analysis

A total of 470 calves had a total protein measurement recorded (59.7 per cent of all calves) and were used as the denominator population. Only 148 (31 per cent) of calves were classed as having FPT due to a total protein <5.2 g/dl. The power of the logistic regression analysis for the association between the total protein level and development of clinical signs ranged from 5 per cent for joint ill to 70 per cent for pyrexia. The total protein level was only significantly associated with the development of pyrexia ($P<0.01$), with calves that had failure of passive transfer having 2.4 higher odds of developing pyrexia as a preweaning calf (table 4). The area under the ROC curve for predicting pyrexia development was 0.60 (se 0.030), with a cut-off value for classification of failure of passive transfer of 5.5 g/dl giving a sensitivity of 63.7 per cent and specificity of 50.6 per cent, whereas a cut-off value of 6.5 g/dl had a sensitivity of 93.5 per cent and a specificity of 89.0 per cent.

Table 3: The number of calves experiencing multiple concurrent severe clinical scores at each calf scoring session

The combination of clinical signs detected at each calf score	Number of severe individual calf score recordings	Per cent of scores that were severe
Pyrexia and ocular discharge	330/4738	6.96
Pyrexia and cough	90/4738	1.90
Pyrexia and diarrhoea	53/4738	1.12
Pyrexia and nasal discharge	22/4738	0.46
Pyrexia, cough and diarrhoea	14/4738	0.30
Pyrexia, cough and nasal discharge	13/4738	0.27
Pyrexia, cough and ocular discharge	12/4738	0.27
Diarrhoea and cough	46/4738	0.97
Diarrhoea and ocular discharge	40/4738	0.84
Diarrhoea and nasal discharge	16/4738	0.34
Cough and nasal discharge	32/4738	0.68
Ocular discharge and nasal discharge	30/4738	0.63

Preweaning mortality

A total of 12.7 per cent (100/787) of all calves died during the preweaning period at a mean age of 16 days old (range 2–56 days old). Of the original 787 calves, 433 either died or had a complete set of eight scores at weekly intervals, and so acted as the denominator population for analysis by time-dependent Cox regression for preweaning mortality. This demonstrated that having been pyrexic, had a cough or nasal discharge were significantly associated with death during the preweaning period (table 5). Fifty-five (12.7 per cent, 55/433) calves died without having been recorded as having any significant calf scores in the preweaning period before their death. The power of the Cox regression analysis for identifying a significant association with the clinical health scores was >80 per cent for having a cough, being pyrexic, having nasal and ocular discharge and being in a group pen. The power was <80 per cent for the remaining parameters.

Postweaning mortality

Of the calves that survived the preweaning period, a further 10 per cent (69/687) died during the postweaning period up to 14 months of age (which is when the beef animals were sold from the farm and so further follow-up was not possible). Combined with preweaning figures, this gave an overall calf mortality rate of 21.5 per cent (169/787) up to 14 months of age on this farm.

Associations between postweaning mortality and preweaning disease were assessed using a denominator population of 333 calves that had a complete set of eight calf scores. Calves that experienced an abnormal clinical score for cough were more likely to die (HR 2.5, $P=0.023$) and died sooner (Cox regression average day at death 420 v 442 days, $P=0.03$) (Fig 3), as did calves with a rectal temperature ≥39.5°C, that had a higher HR for death (HR 2.2, $P=0.006$) and died sooner (Cox regression average day at death 418 v 442 days, $P=0.03$) (Fig 4).

The power of the Cox regression analysis for identifying a significant association with the clinical health scores was >80 per cent for having diarrhoea, nasal and ocular discharge. The power was <80 per cent for the remaining parameters.

Production parameters in primiparous heifers

For the outcome of age at conception, 187 individual primiparous heifer records were used as the denominator population (table 6).

Table 4: The ORs with 95% CI and P values associated with the development of clinical health scores, shown with their associations to the covariates of total protein levels, sex and whether it was a beef crossbred calf. Pyrexia was defined as a rectal temperature ≥39.5°C

Clinical sign measured	Total protein (>5.2 g/dl) OR (95% CI)	P value	Sex (female) OR (95% CI)	P value	Breed (Holstein-Friesian) OR (95% CI)	P value
Pyrexia	2.40 (1.56 to 3.68)	<0.01	0.74 (0.32 to 1.73)	0.49	0.66 (0.28 to 1.52)	0.33
Diarrhoea	1.34 (0.90 to 1.99)	0.16	0.56 (0.28 to 1.12)	0.10	0.44 (0.22 to 0.88)	0.02
Cough	1.32 (0.88 to 1.98)	0.18	0.70 (0.33 to 1.48)	0.35	0.66 (0.31 to 1.39)	0.27
Ocular discharge	0.59 (0.34 to 1.02)	0.060	0.96 (0.41 to 2.25)	0.93	1.44 (0.61 to 3.44)	0.41
Nasal discharge	1.86 (0.97 to 3.60)	0.063	1.30 (0.41 to 4.11)	0.76	1.19 (0.38 to 3.74)	0.65
Navel ill	1.21 (0.65 to 2.24)	0.55	0.18 (0.024 to 1.36)	0.097	0.22 (0.029 to 1.70)	0.15
Joint ill	1.24 (0.29 to 5.29)	0.76	0.90 (0.88 to 1.23)	0.99	0.90 (0.87 to 1.18)	0.99

Joint ill was excluded from the model as there was only one HF heifer surviving to first lactation with an abnormal clinical score for this condition. The mean age at conception was 469 days old. For the assessment of 305-day milk yield in primiparous heifers, 150 individual animal records were complete and available at the time of analysis, with a total of 969 individual preweaning calf scoring visits (an average of seven visits per heifer).

None of the measured health scores were significantly associated with the age at conception or the 305-day milk yield. Backwards removal of potentially correlated variables did not lead to development of a significant relationship between any of the calf health measures and the production outcomes. The power of the linear regression model for identifying a significant association with the clinical health scores was >80 per cent for having a cough, being pyrexic and having nasal and ocular discharge. The power was <80 per cent for the remaining parameters.

Discussion

This study followed 787 calves over a two-and-a-half-year period with once weekly calf scoring and veterinary assessments of health during the preweaning period to evaluate how this impacted on subsequent mortality rates and productivity. As such, it represented a rare opportunity to gather detailed health data using a relatively new scoring method. The scoring system was based on the Wisconsin Calf Health Score,[13] which assigned a numerical health score to a calf for nasal discharge, ocular discharge, coughing, rectal temperature, faecal score, joint ill and navel ill. Its aim was to provide a means of increasing the sensitivity of detection of diseased animals by serving as an objective and systematic screening tool.

The study demonstrated calf scoring was an appropriate method for identification of clinical signs associated with disease in calves as shown by the high level of morbidity detected using this method. Eighty-seven per cent of calves (685/787) had at least one abnormal clinical score observed during their preweaning period; however there were low numbers of calves (16 per cent, 755/4738) that had multiple clinical signs recorded at a single time point (table 3). This may have been due to the high prevalence of diarrhoea (57.6 per cent), which in uncomplicated cases may not show further clinical signs. The effect of less severe clinical scores was not investigated due to dichotomising of the calf scoring system. This was carried out by only assessing the effect of Wisconsin Score 2 and 3 signs on the outcome parameters, and was done to try and reduce differences between different observer scores. In addition to this, future investigations into the temporal association between occurrence and development of clinical signs could be assessed to establish if the occurrence of each clinical sign is associated with development of the others.

Table 5: The HRs and 95% CI based on time-dependent Cox regression analysis for the abnormal clinical scores significantly associated with death of a calf during the preweaning period. Pyrexia was defined as a rectal temperature ≥39.5°C

Variable	HR (95% CI)	P value
Pyrexia	0.54 (0.37 to 0.78)	<0.001
Diarrhoea	1.31 (0.81 to 2.13)	0.27
Cough	3.48 (1.81 to 6.69)	<0.001
Ocular discharge	0.32 (0.045 to 2.33)	0.26
Nasal discharge	5.11 (2.02 to 12.96)	<0.001
Navel ill	0.91 (0.29 to 2.88)	0.87
Joint ill	3.87 (0.54 to 27.8)	0.18
Failure of passive transfer	1.0 (0.94 to 1.03)	0.76
Group pen	0.28 (0.93 to 2.80)	0.092
Sex	0.21 (0.64 to 1.44)	0.83

During the study period, there was a preweaning mortality rate of 12.7 per cent, with the mean age of death being 16 days old. Of the preweaning calf deaths in this study, 55/787 calves did not have any abnormal calf scores recorded for the period between birth and death. The early infection of calves by pathogenic organisms in conjunction with ineffective detection and lack of treatment protocols adopted by the farm labourer possibly contributed to some of the high mortality levels seen. This infers a disease pathology involving diarrhoea, which in severe and untreated cases can lead to death due to dehydration and hypovolaemia, and is supported by previous studies that demonstrated diarrhoea has been responsible for more than 50 per cent of unweaned dairy heifer deaths.[18] However, a limitation of the study was the lack of diagnostic investigation for both disease pathogen identification and cause of death, meaning these conclusions cannot be proven.

The postweaning mortality rate was 10 per cent up to 14 months of age, which is quite high compared with rates reported in Finland of 5.7 per cent,[19] and in France of a 3.1 per cent rate for heifers aged one to six months old.[20] This study showed that calves that had experienced coughing had an increased risk of postweaning death (P=0.023), which may indicate that prewean-

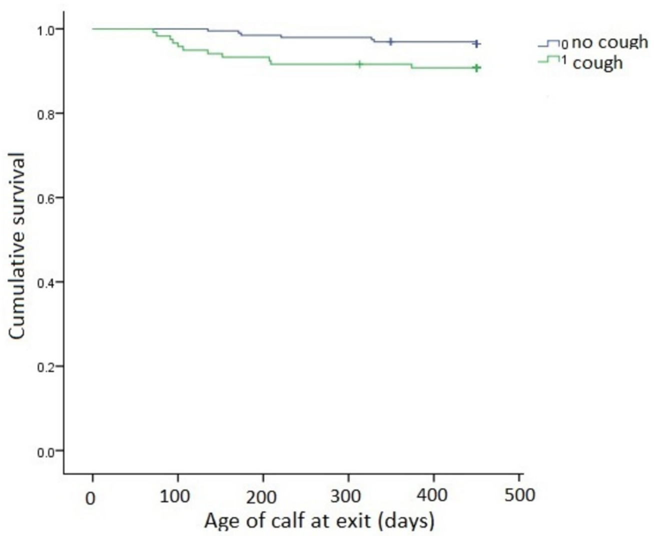

FIG 3: Kaplan-Meier survival curve comparing the age of death for calves that did and did not experience an abnormal clinical score for cough as a preweaning calf.

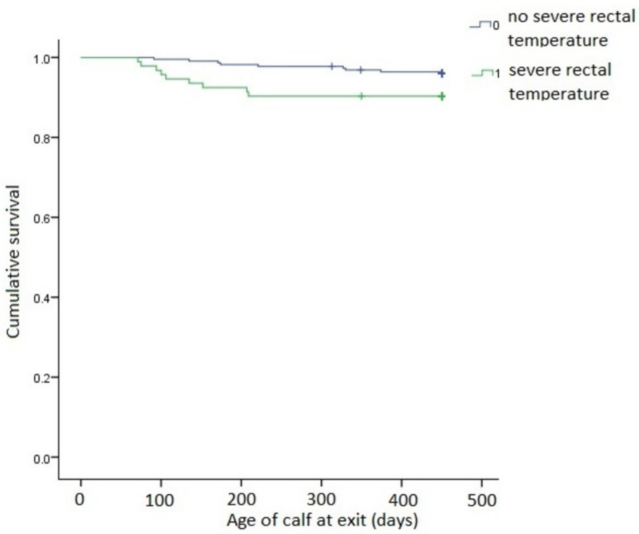

FIG 4: Kaplan-Meier survival curve comparing the age of death for calves that did and did not experience an abnormal clinical score for rectal temperature as a preweaning calf.

ing pneumonia had led to reduced lung function and increased susceptibility to future severe pneumonia occurrence, and therefore death.

Of the HF heifers born alive, only 81 per cent reached calving age, which is 4 per cent lower than the mean rate reported in the UK for the same period.[21] Further analysis showed calves with a cough had nearly a 3.5 times higher hazard of dying during the preweaning period (P<0.001) and died at a younger age postweaning (22 days earlier, P=0.003). Previous studies have also shown that heifers treated for pneumonia during their first three months of life are more likely to die after 90 days of age ,[22] with heifers suffering from four or more episodes of respiratory disease being 1.9 times less likely to reach the end of their first lactation.[23] In addition, calves with nasal discharge had an increased hazard of dying preweaning (HR 5.11, P<0.001). These respiratory disease clinical signs were successfully detected using the calf scoring system, indicating the usefulness of the method for detection and initiation of treatment in these animals.

Calves with pyrexia (rectal temperature ≥39.5°C) during the preweaning period had a decreased hazard of dying as a preweaning calf (HR 0.54, P<0.001). This perhaps highlights a potentially positive sign in pyrexia, which is one of the first physiologically protective changes to be detected in response to infection and inflammation, with pyrexia shown to typically develop between 12 and 136 hours before the onset of clinical signs of pneumonia.[24] This may have meant that the initiation of treatment upon detection of pyrexia (generally an NSAID drug treatment in this study) prevented the development of furthermore severe clinical signs of pneumonia, so resulting in a lower mortality during the preweaning period and better long-term results for calf health as shown by the increased milk yield.

It has been shown that an increased detection rate of sick calves is achieved using calf scoring twice per week.[3] The high mortality in this study suggests diseased calves may have been missed, either due to poor detection at scoring or more likely, due to the seven-day gap between scoring sessions. This serves to highlight the critical importance of continuous detection of disease, and with the advent of various monitoring technologies such as devices for assessing body temperature, it may now be possible to provide continuous monitoring of calf health for farmers. This should further reduce the time lag between disease onset and detection.

Four hundred and seventy calves were assessed for the effectiveness of colostral passive transfer of immunity through the monitoring of serum total protein, with 31 per cent being classed as having FPT (serum total protein <5.2 g/dl). The study farm used a protocol of feeding two litres of colostrum to calves, which is less than the current recommendation of approximately 10 per cent of the calf's body weight or approximately three litres of colostrum should be given within 12 hours of birth.[25] Calves depend on ingestion of colostrum during the first 24 hours of life to acquire maternally derived antibodies, with FPT considered a predisposing factor for most early neonatal infectious disease losses.[26] Surprisingly, only the development of pyrexia was significantly associated with the level of total proteins (P<0.01). This is consistent with the study by[27] who found that the risk of caregiver-diagnosed pneumonia was not affected by low IgG levels. The lack of association of total protein levels with occurrence of the other clinical signs may have been due to the low power of this analysis, which ranged from only 5 per cent power for detecting an association of total protein level with development of joint ill, up to 70 per cent power for pyrexia. For some pathogens (like *Cryptosporidium parvum*) the level of hygiene is an important risk factor for the incidence of disease.[28] As the level of diarrhoea was high in this herd, a lack of hygiene could have contributed significantly to the level of disease in this herd and therefore decreasing the significance of FPT.

Given that this was a single farm study conducted on a farm with high morbidity and mortality levels compared with figures cited in the literature, the results must be interpreted cautiously. During the study period, there were several management changes (Fig 1) including the addition of a treatment with an NSAID at disbudding and a change from indoor, group-housed calves to outdoor, individual hutch-housed calves with improved hygiene. These were included in the models during analysis and were not found to be influential on outcomes, and so ruled out as confounders. During the study period, 302 calves did not receive all eight of their weekly calf scores, so excluding them from the analysis of the risks associated with postweaning deaths. These calves may not have received a recorded health score due to planned vis-

Table 6: The coefficients and se's for the abnormal clinical health that occurred during the preweaning period, associated with the production parameters of age at conception and 305-day milk yield of Holstein-Friesian heifers. Pyrexia was defined as a rectal temperature ≥39.5°C. An example interpretation of the data is that a calf that experienced pyrexia as a preweaning calf was 25 days older when she conceived and gave 233.99 kg less milk than a calf that did not experience pyrexia

Clinical health score	Age at conception (days) Coefficient (se)	P value	305-day milk yield (kg) Coefficient (se)	P value
Pyrexia	25.14 (13.23)	0.060	233.99 (465.74)	0.62
Diarrhoea	−6.08 (11.70)	0.61	229.24 (413.87)	0.581
Cough	8.98 (11.38)	0.43	−780.18 (397.32)	0.53
Ocular discharge	−13.59 (15.18)	0.37	−299.47 (484.93)	0.54
Nasal discharge	−21.96 (19.10)	0.25	776.98 (730.74)	0.29
Navel ill	−18.13 (17.70)	0.31	−1018.25 (609.10)	0.098
Joint ill	−28.22 (62.37)	0.65	−161.08 (1982.65)	0.935
Failure of passive transfer	2.46 (12.13)	0.84	423.45 (433.44)	0.33
Group pen	5.22 (13.89)	0.71	−863.22 (456.86)	0.062

itations falling during university holiday periods. Although this led to a reduction in some of the available data, and potentially introduced a source of bias, there was still a large data set used.

Conclusion

This study used an objective and systematic calf scoring system to enable early detection of calves displaying signs of clinical disease. This methodology led to high recorded levels of morbidity with a consistent demonstration of pyrexia and coughing being risk factors for mortality. Regardless of the identification of these neonatal calf diseases, mortality on this farm was approximately three times higher than target levels, demonstrating that once weekly detection of disease alone is insufficient to prevent all deaths. However, the calf scoring method may assist in early detection to reduce the severity of disease enough to prevent negative effects on future performance.

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Assessing the effects of weekly preweaning health scores on dairy calf mortality and productivity parameters: cohort study

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