**The association of neonatal calf diarrhoea with and without dehydration on milk feeding and activity variables in young pre-weaned artificially reared calves**

**Application:** An understanding of changes in automatically detected behaviours in neonatal calf diarrhoea (NCD) and concurrent dehydration allows the development of automatic disease detection tools. Early detection of neonatal calf diarrhoea and concurrent dehydration will improve calf outcomes.

**Introduction:** NCD is a frequent disease in young calves, which can lead to dehydration. Both conditions are a welfare and production concern.The objective of this study was to identify changes in activity and feeding variables that are associated to NCD, with or without dehydration.

**Materials and methods:** One hundred and forty-one calves were moved into group-housing at approximately seven days of age, at which point they entered the trial. The calves were then followed until 25 days of age or three days after the development of NCD. Calves were health scored daily as follows: Wisconsin health score (McGuirk, 2008) for respiratory disease, faecal consistency (Faeces, Table 1), hind leg tail and perineum cleanliness (CLEAN, Table 1) and skin tent elasticity. Calves with a faeces score of two or above were classified as having NCD. Calves that had a return of the skin tent in less than three seconds were classified as NCD-Hydrated (NCD-H). Those with a delayed return of the skin tent were classified as NCD-Dehydrated (NCD-D). To remove any effect of bovine respiratory disease, all calves that had a Wisconsin health score that was classified as diseased (>4) had that day and three days either side removed from the dataset. Rectal temperature (recorded daily as part of the Wisconsin Score) was converted to a four-level categorial variable (Temperature, Table 1).

Table 1 The criteria for the tail, perineum and hindleg cleanliness, faeces and temperature scores

|  |  |  |  |
| --- | --- | --- | --- |
|  | Scoring criteria | | |
| Score | **CLEAN** | **Faeces** | **Temperature** |
| 0 | Clean calf or with a small amount of dried faeces on tail/perineum/hind legs | Formed faeces | 37.9-38.3°C |
| 1 | A large amount of dried faeces or some pasty faeces on tail/perineum/hind legs | Pasty faeces | 38.4-38.8°C |
| 2 | Wet Faeces on tail/perineum/hind legs | Loose faeces that did not sift through bedding | 38.9-39.4°C |
| 3 | A very wet tail/perineum or a large amount of faeces on tail/perineum/hind legs | Liquid faeces that sifted through the bedding | ≥39.5°C |

Milk feeding behaviours were measured using automatic milk feeders (*Biocontrol*). Calves had access to 7 L of acidified milk replacer daily. Activity variables were measured using a triaxial accelerometer (*IceQube*) attached to the left hind leg. The behaviours measured for each calf were; total time at milk feeder, total milk visits, mean milk visit length, mean milk drinking speed, volume of milk drunk each day, mean milk per visit, daily lying time, daily standing time, daily lying bouts, daily standing bouts, total daily motion index, mean lying bout length, mean standing bout length and mean motion index per standing bout.

General linear mixed modelling was carried out using the lme4 library in R studio (Bates *et al.*,2015). Disease status, season, sex, sire breed type, temperature score, age and the interactions between disease status and age, disease status and season, and disease status and temperature score were tested as fixed effects. Backwards model selection by AIC was carried out using the step() procedure in R. The calf number nested within pen was included in all models as a random effect.

**Results:** There were 1125 healthy, 232 NCD-H and 8 NCD-D days for the lying behaviours and 961 healthy, 249 NCD-H and 8 NCD-D days for the milk feeding behaviours available for analysis. Of the fourteen behaviours analysed, seven had residuals that were not normally distributed, despite attempting transformations. The outputs of the final mixed models whose residuals were normally distributed are summarised for the activity and milk feeding behaviours in Tables 2 and 3 respectively.

Table 2 The effect of neonatal calf diarrhoea with or without dehydration on activity behaviours of young pre-weaned artificially reared calves1. Factors with p<0.05 are shown in bold.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Behaviour | Fixed effect | Level | Effect size | Confidence interval | P value |
| Daily lying bouts (n) | Disease status | Healthy | Reference | Reference | Reference |
| **NCD-H** | **-1.100** | **-1.245 - 1.060** | **<0.001** |
| NCD-D | -1.180 | -1.396 - 1.000 | 0.052 |
| Sire breed type | Beef | Reference | Reference | Reference |
| **Dairy** | **-1.097** | **-0.852 - -0.975** | **0.009** |
| Season | Autumn | Reference | Reference | Reference |
| **Winter** | **-1.208** | **-0.780 - -1.144** | **<0.001** |
| **Spring** | **-1.118** | **-1.187 - -1.054** | **0.005** |
| Daily standing bouts (n) | Disease status | Healthy | Reference | Reference | Reference |
| **NCD-H** | **-1.100** | **-1.141 - 1.060** | **<0.001** |
| **NCD-D** | **-1.183** | **-1.399 - 1.000** | **0.048** |
| Sire breed type | Beef | Reference | Reference | Reference |
| **Dairy** | **-1.099** | **-0.851 - -0.973** | **<0.001** |
| Season | Autumn | Reference | Reference | Reference |
| **Winter** | **-1.210** | **-0.779 - -1.147** | **<0.001** |
| **Spring** | **-1.118** | **-1.186 - -1.054** | **0.004** |
| Mean lying bout length (minutes) | Disease status | Healthy | Reference | Reference | Reference |
| **NCD-H** | **1.094** | **1.051 - 1.139** | **<0.001** |
| **NCD-D** | **1.219** | **1.015 - 1.464** | **0.034** |
| Sire breed type | Beef | Reference | Reference | Reference |
| **Dairy** | **1.086** | **1.010 - 1.167** | **0.027** |
| Season | Autumn | Reference | Reference | Reference |
| **Winter** | **1.227** | **1.150 - 1.308** | **<0.001** |
| **Spring** | **1.095** | **1.026 - 1.169** | **0.020** |
| Total daily activity | Disease status | Healthy | Reference | Reference | Reference |
| **NCD-H** | **-132.342** | **-201.323 - -77.956** | **<0.001** |
| **NCD-D** | **-346.630** | **-852.797 - -67.007** | **<0.001** |
| Sex | Female | Reference | Reference | Reference |
| **Male** | **-17.364** | **-58.99 - -0.487** | **0.021** |
| Season | Autumn | Reference | Reference | Reference |
| **Winter** | **-65.545** | **-152.157 - -15.029** | **<0.001** |
| Spring | 21.132 | -86.220 - 0.016 | 0.074 |
| **Disease status x Season** | |  |  | **<0.001** |
| Mean activity per standing bout | Disease status | Healthy | Reference | Reference | Reference |
| **NCD-H** | **1.233** | **-2.519 - -0.407** | **<0.001** |
| **NCD-D** | **10.093** | **-28.490 - -1.086** | **0.004** |
| Sire breed type | Beef | Reference | Reference | Reference |
| **Dairy** | **1.018** | **0.020 - 3.439** | **0.022** |

1 The results shown for the models where a transformation was used have been back transformed.

Table 3 The effect of neonatal calf diarrhoea with or without dehydration on milk feeding behaviours of young pre-weaned artificially reared calves1. Factors with p<0.05 are shown in bold.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Behaviour | Fixed effect | Level | Effect size | Confidence interval | P value |
| Total milk visits (n) | Disease status | Healthy | Reference | Reference | Reference |
| **NCD-H** | **0.079** | **0.000 - 0.293** | **0.037** |
| NCD-D | 0.055 | -0.880 - 1.999 | 0.697 |
| **Age** | | **0.002** | **0.002 - 0.003** | **<0.001** |
| Season | Autumn | Reference | Reference | Reference |
| **Winter** | **0.004** | **-0.118 - -0.008** | **0.001** |
| Spring | 0.048 | 0.044 - 0.006 | 0.379 |
| **Disease status x Season** | |  |  | **0.005** |
| **Disease status x Age** | |  |  | **<0.001** |
| Mean milk visit length (minutes) | Disease status | Healthy | Reference | Reference | Reference |
| **NCD-H** | **1.207** | **1.143 - 1.025** | **<0.001** |
| **NCD-D** | **1.674** | **1.350 - 2.079** | **<0.001** |
| **Age** |  | **-0.977** | **-0.969 - -0.977** | **<0.001** |
| Season | Autumn | Reference | Reference | Reference |
| Winter | -0.963 | -0.932 – 1.152 | 0.516 |
| Spring | -0.914 | -1.253 - 1.046 | 0.201 |
| **Disease status x Season** | |  |  | **0.044** |

1 The results shown for the models where a transformation was used have been back transformed.

**Conclusion**: Calves with NCD-H have fewer standing and lying bouts, longer lying bouts, are less active, visit the milk machine more often and have longer visits to milk when compared to their healthy counterparts. Similar results were seen for calves with NCD-D, however dehydration did not have a statistically significant impact on total milk visits and daily lying bouts, most likely due to the small number of NCD-D days. The interaction between disease status and season may reflect a differing response to environmental conditions depending on disease status. The interaction between disease status and age in the number of visits to milk may reflect a differing response to disease as calves grow. The association of NCD-H and NCD-D with changes in behaviour suggests that there is potential for these behaviours to be used in automatic disease detection tools, however factors such as age and season must also be considered.

**Acknowledgements:** The authors wish to thank the farm and technical staff at SRUC Dairy Research & Innovation Centre, Crichton Royal Farm, Dumfries for their assistance. BRs PhD is funded by EASTBIO DTP and AHDB. SRUC receives funding from RESAS, Scottish Government.

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