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Alteration of activity variables relative to clinical diagnosis of bovine respiratory disease in newly received feedlot cattle

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Abstract

Our objective was to explore change in activity variables relative to clinical identification of bovine respiratory disease (BRD) in cattle maintained in a commercial feedlot. Four blocks (n = 364) of high-risk, crossbred beef calves were affixed with an accelerometer device upon feedlot arrival that continuously logged activity variables (standing time, step count, lying bouts, motion index) for a 56-day period. Overall, 51.5% of calves were diagnosed at least once with BRD, while 15.2 and 4.5% had a second and a third BRD event, respectively. The level of activity in cases was compared with that of control cohorts relative to the time of BRD diagnosis in cases. Reductions in activity variables in cases started at least 6 days prior to BRD diagnosis, and were more pronounced the day before disease identification. All activity variables were reduced ($P \leq 0.01$) at day -1 for cases vs controls. Average standing time on the day prior to diagnosis (day -1) was 559 minutes for cases compared to 613 minutes in controls. Step count on day -1 for cases and controls were 843 and 1,472 steps, respectively. The number of lying bouts for cases and controls was 11.4 and 14.5, respectively on day -1. Activity information provided by accelerometers, used as an objective method for identification of BRD in cattle, may assist in management and early detection of sick cattle.

Key words: accelerometers, activity, bovine respiratory disease, feedlot cattle

Résumé

Notre objectif était d'explorer l'association entre le niveau d'activité et l'identification clinique du complexe respiratoire bovin (CRB) chez des bovins dans un parc d'engraissement commercial. À leur arrivée au parc d'engraissement, on a fixé un accéléromètre sur des veaux de boucherie de race croisée à haut risque (n = 364) divisés en quatre blocs. L'accéléromètre pouvait enregistrer en temps continu des variables reliées à l'activité (le temps passé debout, le nombre de pas, le nombre de périodes couchées et un indice de mobilité) sur une période de 56 jours. Au total, le CRB a été identifié au moins une fois chez 51.5% des veaux, deux fois chez 15.2% des veaux et trois fois chez 4.5% des veaux. Le niveau d'activité chez les cas a été comparé à celui des témoins de la cohorte tenant en compte le moment du diagnostic du CRB chez les cas. Une réduction de l'activité chez les cas a été observée au moins six jours avant le diagnostic du CRB et était plus prononcée le jour avant l'identification de la maladie. Une réduction de l'activité au jour -1 chez les cas par rapport aux témoins a été observée pour toutes les variables reliées à l'activité ($P \leq 0.01$). Avant le diagnostic (jour -1), le temps moyen passé debout était de 559 minutes chez les cas et de 613 minutes chez les témoins. Au jour -1, le nombre de pas était de 843 chez les cas et de 1472 chez les témoins. Toujours au jour -1, le nombre de périodes couchées était de 11.4 chez les cas et de 14.5 chez les témoins. En tant qu'outil pour l'identification objective du CRB chez les bovins, les données de l'accéléromètre sur l'activité pourraient assister la régie et la détection précoce des bovins atteints.

Introduction

Bovine respiratory disease (BRD) is the most commonly diagnosed and economically detrimental health disorder in the cattle feeding industry in the United States,[24,31] and its etiology is broadly described as infectious pneumonia with pulmonary lesions. However, BRD can be defined more specifically as the result of multifaceted infectious and noninfectious factors and delicately intertwined interactions between various stressors, host immunity, and pathogenicity of agents that alter the susceptibility in an individual in which at least 1 bacterial organism is cultured.[4] Current BRD diagnostic methods are reliant upon subjective visual appraisal of clinical signs, such as depression; lethargy; anorexia; nasal; oral, and ocular discharge; fever; cough; altered respiratory character; and dyspnea. This approach to BRD diagnosis in commercial feedlots has remained unchanged over the last several decades, and sensitivity and specificity of current BRD diagnostic methods are estimated to be 61.8 and 62.8%, respectively.[25] One critical element in successful BRD treatment is timely identification of clinical signs; however, availability of trained personnel is becoming a limiting factor to the cattle feeding industry. Field diagnoses of BRD by pen riders may be influenced by the nature of cattle that, being prey animals, tend to disguise sickness behavior and vulnerability upon human approach.[6,20,21] Animals' behavioral response to illness could be used in the clinical diagnosis of disease, including BRD.[30] Accelerometer devices provide accurate standing/lying duration, step count, and frequency of activity with no effect noted for variable placement of the accelerometer.[5,12] High agreement between accelerometers and video recording for lying (inverse of standing) activity has been observed, with 99.2% accuracy; whereas, agreement on walking (step count) has also been reported, with 67.8% accuracy, potentiating accelerometer use as a precise, non-invasive and remote measure of cattle behavior.[12,15,23] A reliable and cost-effective methodology available in real time for improved field diagnosis of BRD is warranted.[29,30] With new technology, such as accelerometers capable of continuous monitoring of activity, advancements can also be made in the understanding of behavior relative to cattle health status. Consequently, our objective was to determine change in activity relative to clinical identification of BRD in newly received beef cattle maintained in a commercial feedlot setting.

Materials and Methods

Animals, Processing, and Feeding

Experimental procedures were approved by the West Texas A&M University Institutional Animal Care and Use Committee (Protocol No. 02-10-13). High-risk cattle of unknown health or management history were enrolled in 4 arrival blocks after purchase from the same auction market located in south Texas. In total, 400 crossbred beef calves (291 bulls and 109 steers; overall initial BW = 387.9 ± 41.4 lb (176.3 ± 18.8 kg)) were enrolled in the study. Three-axis digital accelerometers[a] were placed proximate to the metatarsus of the right-rear leg on 365 head during initial processing, and activity data were successfully retrieved and used in the final analysis from 364 cattle in this study. Cattle were transported approximately 600 miles (970 km) to a commercial feedlot.[b] Castration status was determined during initial processing, that occurred on the day following arrival to the feedlot. Calves were stratified by castration status and assigned randomly to 2 adjacent pens (n = 50 calves/pen) that were reserved for all 4 blocks included in the study. Calves from all 4 blocks were processed identically in accordance with standard operating procedures recommended by the feedlot's consulting veterinarian. Initial processing protocol included parenteral administration of a trivalent modified-live virus respiratory vaccine[c] containing infectious bovine rhinotracheitis virus (IBRV) and bovine viral diarrhea virus (BVDV type 1 and 2); intranasal administration of a trivalent (IBRV, bovine respiratory syncytial virus, parainfluenza-3 virus) respiratory vaccine;[d] and an autogenous *Mannheimia haemolytica* bacterin, administered subcutaneously (SC). Additionally, a *Clostridium chauvoei-septicum-haemolyticum-novi-tetani-perfringens* types C & D bacterin-toxoid[e] was administered SC. An anthelmintic containing ivermectin and clorsulon[f] was administered SC, and a growth implant containing progesterone and estradiol benzoate[g] was administered SC in the caudal aspect of the right ear. Metaphylactic treatment with tilmicosin phosphate injection[h] was administered and a 3-day post-metaphylactic interval was implemented. Cattle were further processed with an ear-notch sample collected from the left ear to test for BVDV persistent infection, administered a unique identification tag in the right ear, horns were tipped, and calves were branded on the right hip with a hot iron. Bulls were castrated with a restrictive rubber band.[i,j]

Block 1 (56 days-on-feed (DOF); January 24, 2014 to March 21, 2014) included 100 calves (76 bulls and 24 steers; initial BW = 365.2 ± 38.7 lb (166.0 ± 17.6 kg)). Accelerometers were placed on 97 calves, of which only 96 were analyzed due to a recording failure in 1 of the accelerometer devices. Calves in block 1 were started on a diet fed twice a day to 30 DOF, transitioned for 7 days with an increasing blend of starter ration and grower ration, and fed for the remainder of the block with grower ration (Table 1). For block 1, cattle were fed twice daily at 07:36 ± 90 minutes and at 12:31 ± 60 minutes.

Block 2 (56 DOF; April 16, 2014 to June 11, 2014) included 100 calves (72 bulls and 28 steers; initial BW = 392.3 ± 37.0 lb (178.3 ± 16.8 kg)). Accelerometers were placed on 69 animals in block 2. Cattle were fed the starter ration twice a day for 29 days, transitioned for 7 days, and fed the grower ration twice a day for the remainder of the block. Average first and second feeding time for block 2 were 07:17 ± 82 minutes and at 12:06 ± 74 minutes, respectively.

Block 3 included 100 calves (69 bulls and 31 steers; initial BW = 386.3 ± 40.7 lb (175.6 ± 18.5 kg)). Accelerometers were placed on all 100 calves in block 3. Cattle were fed the starter ration throughout the entirety of this block (56 DOF; 29 October 2014 to 24 December 2014). Average time of the first feeding was 06:26 ± 17 minutes and the second feeding was 10:29 ± 259 minutes.

Block 4 included 100 calves (74 bulls and 26 steers; initial BW = 407.9 ± 38.3 lb (185.4 ± 17.4 kg)). Accelerometers were placed on 98 of the calves in block 4. Cattle were fed the starter ration throughout the entirety of this block (65 DOF; 17 February 2015 to 23 April 2015); activity data were only analyzed for the first 56 DOF. Average time of the first feeding was 06:33 ± 21 minutes and the second feeding was 11:59 ± 99 minutes.

BRD Case Definition

Clinical BRD diagnosis was determined from an index of visual appraisal of clinical signs and altered behavior. Feedlot personnel were trained to recognize the signs described in both a clinical illness score (CIS) and a depression score (DS) system[13] (Tables 2 and 3). The CIS was used to classify the severity of the illness of cattle, describing the degree of gauntness, nasal and ocular discharge, and labored breathing patterns. Similarly, the depression score was used to classify the severity of depression demonstrated by cattle describing changes in motility and alertness.

Calves were considered a clinical BRD case for the current study if: 1) a score of 1 was determined for both the CIS and DS method, or 2) a score of ≥ 2 was determined for either scoring method. Morbidity and mortality records were acquired from the in-house data management system.[k] Calves not determined to display signs of BRD during the 56-day study period were classified as controls. Calves having at least 1 BRD diagnosis and treated at least once were classified as cases.

Cattle were treated in accordance to a pre-defined antimicrobial regimen upon recommendation of the consulting veterinarian of the facility. After expiration of the post-treatment interval (PTI), cattle were eligible for additional antimicrobial treatment (BRD2 and BRD3, respectively) if clinical signs were presented according to the previously described BRD case definition. Antimicrobial treatments were administered to clinically ill cattle as follows: BRD1 = ceftiofur crystalline free acid,[l] 1.5 mL/100 lb (45.5 kg) BW, SC at the base of the caudal aspect of the ear; BRD2 = florfenicol,[m] 6 mL/100 lb (45.5 kg) BW, SC in the neck; BRD3 = oxytetracycline hydrochloride,[n] 5 mL/100 lb (45.5 kg) BW, SC in the neck. The PTI for BRD1 and BRD2 treatments was 5 and 3 days, respectively. All cattle treated for BRD were returned to their home pen immediately following antimicrobial treatment; there was no separation of healthy cohorts from those diagnosed with BRD.

Accelerometers

Cattle were affixed with the accelerometer device proximate to the metatarsus of the rear-right leg during arrival processing. Of the 400 head enrolled, activity data from 363 head were successfully logged and downloaded using software[o] developed by the manufacturer. The accelerometer devices are a 3-axis accelerometer that generates a change in electrical output voltage relative to the position of the device. The output voltage is translated via proprietary algorithm into duration of standing and lying time (minutes), number of steps taken, number of lying bouts, and a proprietary motion index calculation allowing a detailed report on activity to be quantified. Data from the accelerometers were generated in 15-minute intervals that were then summarized to establish means for each activity variable by day. Alternatively, non-summarized data were analyzed as continuous activity data in 15-minute intervals over a 24-hour period for cases (step count derived from day -1 relative to BRD diagnosis) and controls (average step count derived from the 56-day observation period). Variables reported by the accelerometer device included: 1) standing/lying time (minutes); determined as a sensor passes a specific threshold on a vertical/horizontal

Table 1. Ingredient composition of starter and grower rations.

Ingredient	Percentage*
Starter Ration	
Steam-flaked corn	28.0
Corn gluten pellets	12.0
Corn silage	17.5
Cottonseed hulls	19.0
Wet corn distiller's grains	14.0
Corn condensed distiller solubles/molasses blend	5.0
Liquid supplement	4.5
Grower Ration	
Steam-flaked corn	8.0
Corn gluten pellets	31.0
Corn silage	7.0
Cottonseed hulls	48.0
Corn condensed distiller solubles/molasses blend	3.0
Liquid supplement	3.0

*Values are reported on a dry-matter (DM) basis

Table 2. Definition of clinical illness score.

Clinical illness score*	Description	Appearance
0	Normal	Normal, no signs of clinical illness
1	Slightly ill	Gaunt, nasal/ocular discharge
2	Moderately ill	Gaunt, nasal/ocular discharge, lags behind other animals in the group, cough, labored breathing
3	Severely ill	Purulent nasal/ocular discharge, severely labored breathing, non-responsive to human approach
4	Moribund	Near death

***Clinical illness score[13] (CIS) was determined daily by trained animal health care personnel and used in conjunction with a depression score to determine morbidity of feedlot cattle. Cattle were considered a clinical bovine respiratory disease case if: 1) score of 1 was assigned for both the CIS method and the depression score method (Table 3), or 2) score of ≥ 2 was assigned for either evaluation method.

Table 3. Definition of depression score.

Depression score*	Description	Appearance
0	Normal	Normal, no signs of depression
1	Slightly depressed	Slower than pen mates but still perks up when approached and does not appear weak, actively follows your movements with a raised head
2	Moderately depressed	Stands with head lowered, will perk up when approached but will return to depressed stance, moves slowly and falls towards back of group, may display signs of weakness such as incoordination
3	Severely depressed	Obviously very weak, difficulty in moving with group, raises head only when approached closely
4	Moribund	Near death, non-responsive to human approach

*Depression score was determined daily by trained animal health care personnel and used in conjunction with a clinical illness score (CIS; Table 2) to determine morbidity of feedlot cattle. Cattle were considered a clinical bovine respiratory disease case if: 1) score of 1 was assigned for both the CIS method and the depression score method, or 2) score of ≥ 2 was assigned for either evaluation method.

plane; 2) lying bouts; frequency that each lying activity occurred; 3) motion index; a proprietary index calculated by acceleration on all 3 axes indicative of overall activity; and 4) step count; number of upward movements captured by the device in regards to the force utilized.

Statistical Analysis

Data were organized in spreadsheets[p] and analyzed with statistical software,[q] with individual animal serving as the experimental unit. Activity variables (reported in 15-minute intervals) were summarized by day and organized to compare controls to clinical BRD cases. As data were likely confounded due to pen removal to administer the antimicrobial treatment regimen, activity on the day of antimicrobial treatment (day 0) was omitted from the current analysis. Differences in individual activity variables (step count, motion index, lying bouts, and standing time) between day -1 and the average for day -5 to -3 were compared between cases and controls using PROC MIXED. Daily means for activity variables in cases for the 6 days prior to clinical BRD diagnosis were compared to those of pen mate controls during the same period of time. The effect of BRD status (cases vs controls), day relative to clinical BRD diagnosis of cases (day), and their interaction were analyzed for each activity variable between day -6 to -1 by use of PROC MIXED with repeated measures. The repeated statement was day and the autoregressive covariance structure was used. If a significant interaction was present for a specific activity variable, the differences in daily activity means within day relative to BRD diagnosis were further tested using the PDIFF statement. In addition, the step count for cases and controls was summarized using data in 15-minute intervals to provide activity levels reported on a 24-hour basis. These data were also tested for the overall effect of BRD status, time (based on 15-minute intervals) and their interaction using PROC MIXED with repeated measures, but differences between cases and controls within a given 15 minute interval are not shown.

Frequencies were calculated for demographic information and categorical outcomes (BRD-associated treatment and death) to determine potential associations among outcomes of interest and selected explanatory variables by use of Chi-square test and logistic regression analysis using PROC FREQ and PROC GLIMMIX, respectively. Explanatory variables considered for these statistical models included block, arrival BW quartile (low (Q1; lower 25% of BW within block); intermediate (Q2-Q3; intermediate 25 to 50% BW within block); and high (>Q3; upper 25% of BW within block), and castration status (bull or steer) upon arrival. For all analyses, statistical significance was established at $P \leq 0.05$, whereas a trend was considered for $0.05 > P < 0.10$.

Results and Discussion

Demographics and BRD Incidence

Percentage of calves diagnosed with BRD at least 1 time was 49, 23, 62, and 71.6% for blocks 1, 2, 3, and 4, respectively. Overall, 51.5% of the calves were diagnosed at least once with BRD, while 15.2 and a 4.5% had a second and third BRD diagnosis during the study period. The overall relapse rate in this study was 29.5%. Considering that the overall incidence of BRD across the industry has been reported to be 16.2%,[24] BRD incidence in our study was high, especially for blocks 3 and 4. Elsewhere, a morbidity rate of 22.2% in recently weaned, single-source calves was reported, while commingled calves had a morbidity rate of 31.9%.[18] Mortality/group in the current study was 4, 2, 11, and 6.9% for blocks 1, 2, 3, and 4, respectively, resulting in an overall mortality rate of 5.9%.

A tendency ($P = 0.10$) for increased BRD morbidity was observed in calves arriving as bulls and subsequently castrated (53.9%), compared to those that were steers at the time of arrival (44.9%). Other studies have reported effects of castration status upon arrival to a stocker or feedlot facility on BRD outcome. In a retrospective analysis, the odds for bulls being clinically diagnosed with BRD at least once were 3.32 times greater than steers.[14] Castration results in increased stress and inflammation; thus, castration upon arrival may have a significant impact on BRD incidence.[3,14,16] However, the increase in BRD morbidity observed for bulls castrated upon feedlot arrival could be confounded by the beneficial contribution of preconditioning or other management practices more likely adopted in those that were castrated prior to arrival.[14,21] The risk of BRD is further influenced by arrival BW and season of arrival.[2]

A difference ($P \leq 0.06$) in BRD morbidity was observed between each of the BW quartiles; cattle in the lightest <25% BW quartile had a BRD incidence of 50.7%; the intermediate BW category (26 to 75% BW quartile) had an incidence of 44.8%, while 38.7% of calves in the heaviest >75% BW quartile were diagnosed with BRD. In agreement with our results, it has been reported previously that a greater arrival BW results in decreased morbidity risk.[2,4] Furthermore, it was reported that calves weighing less than the cohort average were 1.4 times more likely to be diagnosed with BRD.[8] The benefit of additional weight at the time of arrival may be a consequence of preconditioning programs implemented before arrival.[21] However, a clear association between decreased morbidity rates with increased arrival weight has yet to be established.

Activity Change Relative to BRD Diagnosis

The number of steps on day -1 for cases and controls were 843 and 1,472 steps, respectively (Figure 1), and a difference ($P \leq 0.001$) in step count between cases and controls was detected within each of the days evaluated. Cases had a decreased ($P < 0.001$) step count on day -6; 1,185 steps were observed for cases compared to 1,453 steps in control. Steps decreased to 1,111 steps on day -5 and further decreased to 986 steps on day -4 for BRD cases; however, there was not an overall day effect ($P = 0.45$). On day -3, step count for cases had stabilized (860 steps) and remained relatively constant through day -1. Comparatively, the step count of controls was static across day -6 to -1, averaging 1,460 steps/day. The difference between day -1 and day -3 to -5 for number of steps in cases was -123.1 steps compared to 50.0 steps in controls ($P < 0.01$). It was reported elsewhere[28] that distance traveled (i.e., step count) was associated with CIS and negatively associated with the extent of lung consolidation following inoculation with *Mycoplasma bovis*, and suggests this behavior variable may not only detect disease, but differentiate its severity. Likewise, the motion index results from the current study revealed a similar difference between cases and controls over time such that a BRD status × day interaction existed ($P < 0.001$). Cases demonstrated a consistent decrease in motion index from day -5 to -1 compared to a greater, yet static motion index observed for controls during this same time ($P \leq 0.001$). However, day -6 motion index in cases was not different ($P > 0.05$) to that of controls. Previous research[17] that used a custom-built ear tag device to determine an overall activity count in cattle reported a decrease for sick vs healthy steers and corroborates the motion index results in the current study.

The number of lying bouts on day -1 for cases and controls was 11.4 and 14.5, respectively (Figure 2) and there was an effect of BRD status on lying bouts ($P < 0.001$), but no interaction was detected ($P = 0.65$). The difference between day -1 and day -3 to -5 for lying bouts in cases was -0.58 bouts/day, compared to 0.71 bouts/day in controls ($P < 0.01$). Standing time resulted in a BRD status × day interaction ($P = 0.02$); on the day prior to BRD diagnosis (day -1) standing time was 559 minutes for cases compared to 613 minutes in controls ($P < 0.01$). However, no difference was detected between cases and controls for standing time from day -6 to -2 ($P > 0.05$) and there was not an effect of BRD status ($P = 0.14$). The difference between day -1 and day -3 to -5 for average standing time in cases was -26.6 minutes compared to 2.3 minutes in controls ($P < 0.01$). The inconsistent standing time observed for BRD cases in this study is not surprising given the authors' anecdotal observation of variable standing behavior of sick cattle in feedlots; some sick cattle may prefer to stand for long duration to facilitate respiration, while others may prefer recumbence for extended periods to

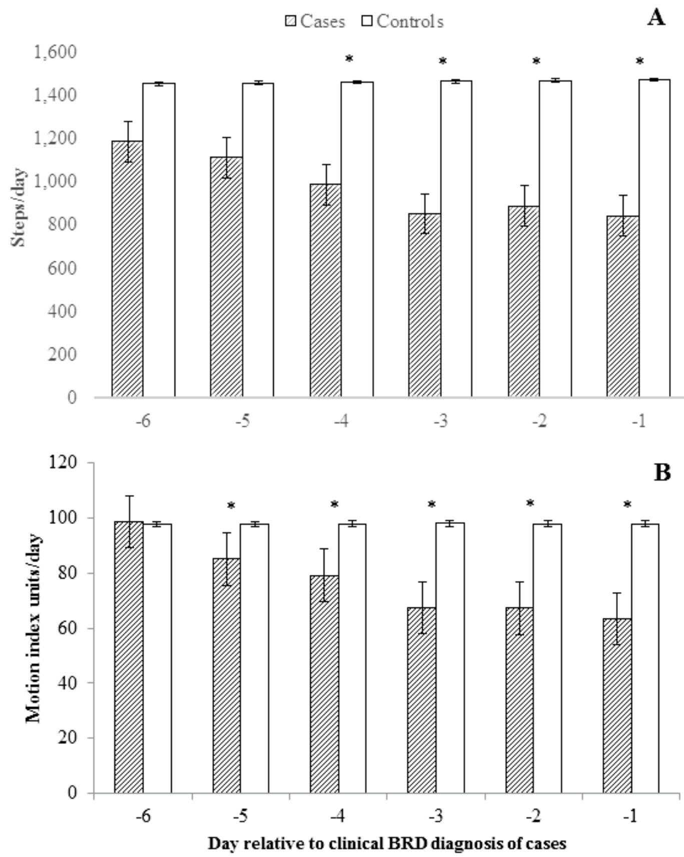

Figure 1. Average steps/day (A) and motion index units/day (B) for clinical bovine respiratory disease (BRD) cases and controls on the day relative to clinical BRD diagnosis in a commercial feedlot. Data were analyzed using the MIXED procedure of SAS with repeated measures and LSMEANS were generated. Effect of BRD status (A: $P < 0.001$; B: $P < 0.001$), day relative to clinical BRD diagnosis of cases (A: $P = 0.45$; B: $P = 0.99$), and their interaction (A: $P < 0.001$; B: $P < 0.001$) were tested. Statistical significance of means within a day relative to clinical BRD diagnosis is indicated with an asterisk, $P \leq 0.01$. Activity variables were determined from an accelerometer device[a] affixed proximate to the metatarsus of the right-rear leg.

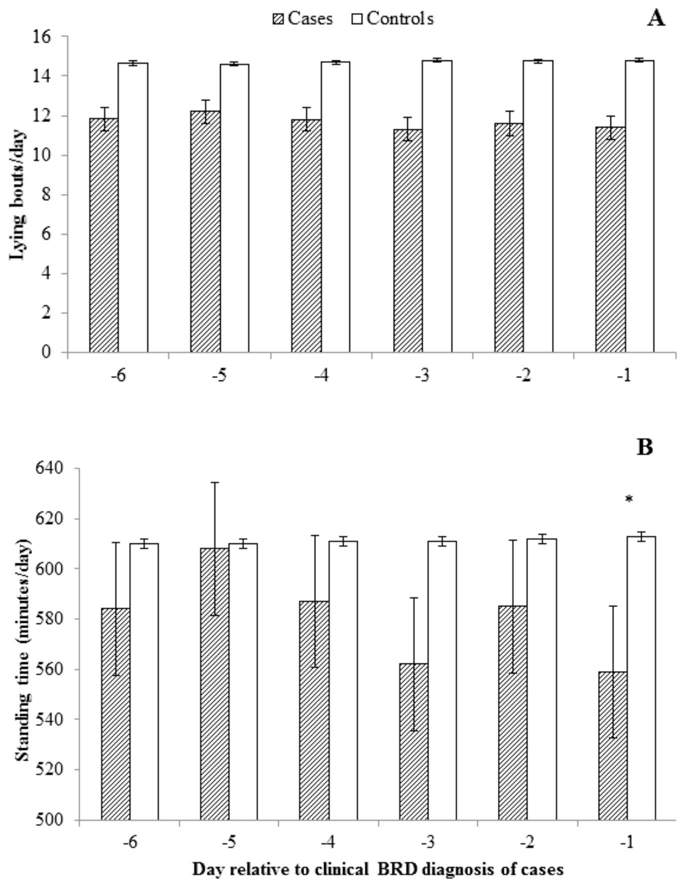

Figure 2. Average lying bouts/day (A) and standing time reported in minutes/day (B) for clinical bovine respiratory disease (BRD) cases and controls on the day relative to clinical BRD diagnosis in a commercial feedlot. Data were analyzed using the MIXED procedure of SAS with repeated measures and LSMEANS were generated. Effect of BRD status (A: $P < 0.001$; B: $P = 0.14$), day relative to clinical BRD diagnosis of cases (A: $P = 0.65$; B: $P = 0.90$), and their interaction (A: $P = 0.65$; B: $P = 0.02$) were tested. Statistical significance of means within a day relative to clinical BRD diagnosis is indicated with an asterisk, $P = 0.001$. Activity variables were determined from an accelerometer device[a] affixed proximate to the metatarsus of the right-rear leg.

conserve energy, and this difference may be due to the time of disease progression or unexplained variability in behavior of sick cattle. Because a difference in standing time was only observed on day -1, it suggests that the other activity variables evaluated in this study may be more effective to detect BRD status early. Nevertheless, calves experimentally challenged with *M. haemolytica* spent more time lying down than control calves.[22]

Biological reasons for decreased activity in animals afflicted with disease include conservation of energy for metabolic costs of the immune system and indirect effects of the febrile and inflammatory response to infection.[7] Prior to administration of *Ostertagia ostertagi* or lipopolysaccharide challenge, cattle spent a greater amount of time standing than lying down, and this activity was inverse 10 hours after cattle had been challenged, and was further associated with clinical depression.[19] It was noted that the most significant behavior change after being exposed to a health challenge was that the duration of lying time increased and the frequency of lying bouts decreased when compared to healthy cattle.[19] Another study[6] reported that the number of steps and standing time decreased after intrabronchial inoculation with *M. haemolytica*. Consequently, continuous monitoring of activity with accelerometers is a promising method for novel disease detection, especially when coupled with other diagnostic methods.[10,29] Activity variables in cattle have also been used successfully to detect lameness,[1,11] estrus,[9,15] and effects of castration.[27] However, it is important to note that the efficacy of other novel diagnostic methods such as feeding behavior, continuous temperature measurements, and serologic biomarkers have also been studied.[10,30] Further research is required to determine the method, or combination of methods that are most effective for early detection of cattle with naturally occurring BRD in the commercial feedlot.

Daily Activity in BRD Cases versus Controls

Throughout the 24-hour period, a bimodal pattern was observed for both cases and controls (time effect; $P < 0.001$); however, controls expressed more noticeable peaks and valleys (Figure 3). The first increase in steps was noted at approximately 05:00 in both cases and controls; this was likely in concert with the anticipation of initial feeding (06:56 ± 67 minutes). Activity decreased near the time of the second feeding, which was 11:31 ± 182 minutes. The second peak in steps occurred in both cases and controls beginning around 16:30, and this decreased at approximately 21:00 for controls and 19:30 for cases. The secondary peak in steps coincides with anecdotal observations of increased animal activity in the feedlot near the time of dusk. A noticeably similar bimodal pattern in the daily activity counts of cattle was observed in a small-pen study conducted in Kentucky with a single feeding time (07:00 to 09:00).[17] This suggests that the bimodal pattern in the activity of cattle throughout a 24-h period may be repeatable across different environments, housing conditions, and feeding regimens. The number of steps was observed to be less for cases throughout the entire day (BRD status effect; $P < 0.001$), with a more profound difference observed later in the day. An inverse bimodal pattern was observed in the difference in the step count (cases - controls).

Conclusions

Each activity variable evaluated in the current study was reduced for BRD cases compared to pen mate controls; however, step count and motion index had the most consistent reduction relative to clinical BRD diagnosis in cases. If the cost benefit and commercial application of accelerometers improve, this methodology may be efficacious for early detection of BRD in the feedlot.

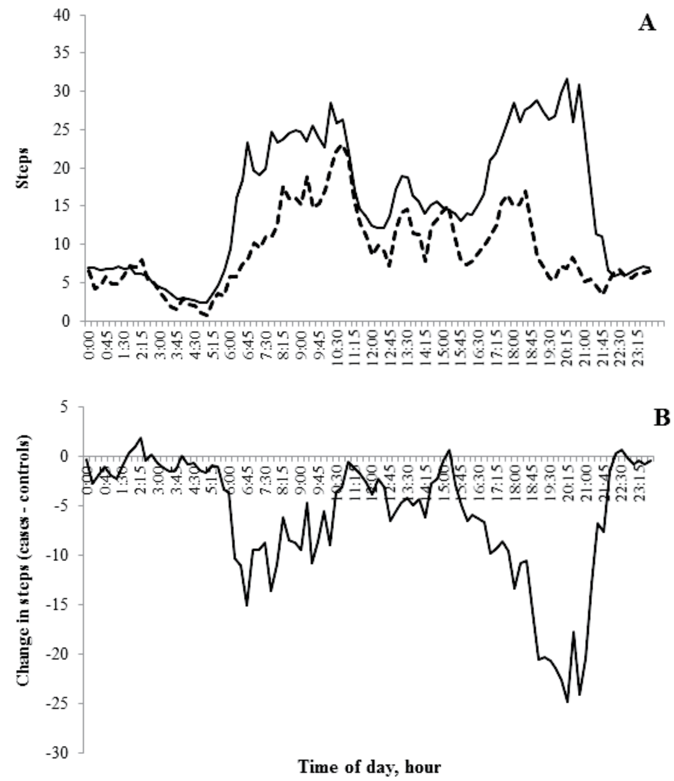

Figure 3. Steps for clinical bovine respiratory disease (BRD) cases (dotted line; step count derived from day -1 relative to BRD diagnosis) compared to control (solid line; average step count derived from the 56-day observation period; A) and change in steps (cases - controls; B) reported continuously over 24-hour period in a commercial feedlot. Effects of BRD status ($P < 0.001$), time ($P < 0.001$) and interaction ($P < 0.001$) for data displayed in A. Feed delivery occurred between 06:00 to 07:30 and 11:59 to 12:31 for first and second feeding, respectively. Activity variables were determined from an accelerometer device[a] affixed proximate to the metatarsus of the right-rear leg.

Endnotes

[a]IceQube, IceRobotics, Ltd., Midlothian, Scotland, UK
[b]OT Feedyard and Research Center, Hereford, TX
[c]Titanium 3, Elanco Animal Health, Indianapolis, IN
[d]Inforce 3, Zoetis, Florham Park, NJ
[e]Covexin 8, Merck Animal Health, Madison, NJ
[f]Ivomec Plus, Merial Limited, Duluth, GA
[g]Component ES, Elanco Animal Health, Indianapolis, IN
[h]Micotil, Elanco Animal Health, Indianapolis, IN
[i]Callicrate, No-Bull Enterprises, St. Francis, KS
[j]Tribander, Wadsworth Manufacturing, St. Ignatius, MT
[k]Animal Health International, Inc., Greeley, CO
[l]Excede, Zoetis, Florham Park, NJ
[m]Nuflor, Merck Animal Health, Madison, NJ
[n]Oxytet 100, Norbrook Inc., Lenexa, KS
[o]IceManager, IceRobotics, Ltd., Midlothian, Scotland, UK, version 2.014
[p]Microsoft Corp., Seattle, WA
[q]SAS Inst. Inc., Cary, NC, version 9.2

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