Bovine respiratory disease continues to be one of the most important diseases of cattle and results in enormous financial losses. It is a multifactorial disease, and the combination of adverse management factors and various bacterial and viral pathogens contributes to the pathophysiology of BRD. The role of BVDV in the pathogenesis of BRD as an immunosuppressive agent and potentiator for other pathogens is well documented.\(^1,2\) Immunosuppression results in both quantitative and functional alterations of the innate and adaptive immune systems.\(^3-6\)

**ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>BRD</td>
<td>Bovine respiratory disease</td>
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<td>BVDV</td>
<td>Bovine viral diarrhea virus</td>
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<td>CIS</td>
<td>Clinical illness score</td>
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<tr>
<td>EMEM</td>
<td>Eagle minimum essential medium</td>
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<tr>
<td>MDBK</td>
<td>Madin-Darby bovine kidney</td>
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<tr>
<td>MEM</td>
<td>Minimum essential medium</td>
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<tr>
<td>VI</td>
<td>Virus isolation</td>
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<td>VN</td>
<td>Virus neutralization</td>
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The prevalence of cattle persistently infected with BVDV at feedlot arrival ranges from 0.15% to 0.4%,\(^1,7\) and those cattle serve as a source of acute BVDV infection for their cohorts. Cattle acutely infected with BVDV can develop disease of varying severity that ranges from subclinical disease to peracute fatal diarrhea and reproductive failure.\(^8\) In addition to immunosuppression, BVDV can cause pneumonitis and the development of clinical signs associated with systemic inflammation and pneumonic damage.\(^9\)

Currently, detection of BRD is dependent on the subjective visual assessment of cattle, which has low diagnostic sensitivity and specificity.\(^10\) Cattle frequently alter their behavior in the presence of human observers, and clinical signs of BRD may not be detected until severe disease has developed. Physical examination, lung auscultation, and clinicopathologic measures of inflammation including alterations in inflammatory cell counts and acute-phase protein concentrations such as haptoglobin concentration have
been used to identify and predict the development of BRD. Those methods are invasive and expensive, and the results may vary depending on the stage of disease that the animal is in when they are performed. Delays in the recognition of cattle with BRD hinder treatment efficacy and success. Furthermore, the inability to reliably detect cattle with mild BRD can lead to underestimation of the production-limiting effect of illness on the behavior of cattle.

Technological advancements allow remote collection of real-time objective measures for numerous physiologic variables in cattle. In field conditions, the use of orbital thermography and rumen boluses to monitor changes in the body temperature of cattle can predict the onset of disease before subjective assessment. Analysis of cattle behavior in the absence of human observers as a method to facilitate early disease detection is garnering interest from the research community and cattle industries, but the technology required for that analysis needs further investigation. Research indicates that the feeding and drinking behaviors of cattle are directly related to health status. Accelerometers and pedometers have been used to monitor cattle activities such as standing, lying, feeding, and drinking and to assess whether changes in those activities can help identify sick cattle. Accelerometers are small noninvasive devices that can objectively monitor cattle behavior remotely with minimal impact on inherent behavior patterns and have been used and validated to describe the behavior of beef and dairy cattle as well as dairy calves. Pedometers are used to measure the overall activity of cattle and have been used in conjunction with accelerometers in multiple studies to characterize the behavior of cattle with experimentally induced BRD. In those studies, the challenge inoculation was intended to induce moderately severe clinical signs and pathology. To our knowledge, information regarding the ability of accelerometers to identify behavioral changes in cattle with subclinical or mild BRD is lacking. The main objective of the study reported here was to assess the use of 3-D accelerometers to evaluate behavioral changes in cattle with subclinical disease induced by experimental infection with a low-virulent strain of BVDV.

Materials and Methods

Animals

Twenty weaned, mixed-breed beef steers that weighed between 216 and 262 kg were obtained from a BVDV-free research herd. Each calf was determined to be free of BVDV and anti-BVDV antibodies on the basis of results of VI and VN, respectively. Calves were weaned and castrated 60 days prior to study initiation and were maintained as 1 group on a biosecure pasture at the North Auburn Beef Unit. Fourteen days prior to study initiation, each calf was randomly assigned by means of random number generator to either a BVDV (n = 10 calves) or control (10) group. Calves in the control group were maintained on a 1-ha biosecure pasture at the North Auburn Beef Unit, whereas the calves in the BVDV group were maintained on a 1-ha biosecure pasture at the North Auburn BVDV Unit throughout the 14-day acclimation period (baseline) and subsequent 35-day study observation period. For both groups, water and Bermuda grass hay were provided ad libitum, and a 12% protein concentrate was fed once daily at a fixed time (5:00 AM) to allow for clinical score assessment. Otherwise, human observation and activity in the vicinity of the pastures were restricted to minimize the effect of human activity on the behavioral data collected. For biosecurity reasons, the veterinarian responsible for clinical score assessment and feeding was aware of (ie, was not blinded to) the treatment group assignment for each calf.

The health of each steer was evaluated by 1 veterinarian (JEB) daily when the protein concentrate was fed. This veterinarian devoted a minimum of 30 minutes for evaluation of each treatment group and visually observed and assigned each steer a CIS on a scale of 1 to 4 (1 = clinically normal, 2 = slightly ill, 3 = moderately ill, and 4 = severely ill) as described. For any calf assigned a CIS of 3 or 4, a physical examination was performed and treatment was administered in accordance with the standard health protocols for the research facility.

Study design

All study procedures were approved by the Auburn University Institutional Animal Care and Use Committee. The study was designed as a randomized controlled trial that consisted of 2 treatment groups (a control group and a group in which BVDV infection was experimentally induced). Power and sample size calculations were performed by use of the a priori function for proportional testing of a commercially available software program as described. Assumptions used for the calculations included 2 treatment groups, a type I error rate of 0.05, and a desired power of at least 90%. It was also assumed that the proportion of time each calf spent walking daily would be 0.2 for calves in the control group and 0.1 for calves in the BVDV group. The calculated total sample size was 16 calves (ie, 8 calves/group), and the calculated power was 95%. Ten calves were assigned to each treatment group to account for potential missing data associated with improperly positioned accelerometers or the need to discard data from some calves during unforeseen handling events.

Calves were inoculated with BVDV or sham inoculated on day 0 and observed for 35 days. On day 7, each calf was restrained in a chute, underwent a physical examination, and had an accelerometer attached to the right hind limb to continuously monitor its activity throughout the observation period. Calves were subsequently restrained in a chute and underwent physical examinations and sample collection at 7-day intervals (days 0, 7, 14, 21, and 28) to minimize periods of altered behavior associated with restraint.
and handling. Calves in the control group were always handled and processed before the calves in the BVDV group to prevent inadvertent exposure of the control calves to BVDV.

**Accelerometers**

A commercially manufactured accelerometer that consisted of a triaxial capacitance type ± 10-g integrated circuit was attached to the lateral aspect of the right hind limb just proximal to the metacarpophalangeal joint as described. The accelerometer was contained in a waterproof case that was padded and strapped to the limb with hook-and-loop straps. The entire system weighed approximately 0.5 kg. Each accelerometer was powered by 2AA lithium batteries and was capable of storing 1 MB of data. Data were continuously collected beginning on day –7 and downloaded weekly on days 0, 7, 14, 21, and 28. To download the data, the accelerometer was removed from the calf’s leg and waterproof case and connected to a laptop computer by a universal serial bus cable. After the data were downloaded to the computer, the accelerometer was placed back into the waterproof case and reapplied to the leg. Data were downloaded on the basis of a user-defined reporting interval (epoch) of 5 seconds and a memory storage capacity of 1 Mb. Commercial data-mining software was used to transform the data into a uniform structure for comparison and analysis. Individual calf behavior at each epoch was categorized as walking, standing, or lying as described and validated. Because downloading data from the accelerometer required that the calf be restrained and restraint affects behavior, the behavioral data collected 30 minutes before and 1 hour after restraint were discarded from all analyses to minimize any bias that handling and restraint might have on behavior.

**Experimental inoculation**

On day 0, each calf in the BVDV group received 2 mL of BVDV type 2 strain 134F (10⁵ TCID₅₀/mL) in each nostril, and each calf in the control group received 2 mL of BVDV-free medium in each nostril. We had used this noncytopathic BVDV type 2 strain 134F to experimentally infect cattle with BVDV prior to the study and determined that it induced mild clinical disease. The BVDV strain was propagated in MDBK cells in EMEM supplemented with 10% equine serum, l-glutamine (200mM), penicillin G (100 U/mL), and streptomycin (100 µg/mL). Bovine viral diarrhea virus was harvested from cells by 1 freeze-thaw method, divided into 2.0-mL aliquots, and stored at -80°C until used. The viral titer was enumerated prior to inoculation of calves as described.

**Blood sample collection**

From each calf, a blood sample was collected by jugular venipuncture into an evacuated blood collection tube that contained sodium EDTA as an anticoagulant (10 mL) and an evacuated tube without any additives (10 mL) on days -7, 0, 7, 14, 21, and 28. Blood samples were submitted to the Clinical Pathology Laboratory at the Auburn University College of Veterinary Medicine for analysis.

**Clinical pathology**

A CBC and serum biochemical analysis were performed in accordance with standard laboratory methods on blood samples collected on days -7, 0, 7, 14, 21, and 28. Aliquots of serum samples obtained on days 0 and 7 were frozen and stored at -80°C for determination of haptoglobin concentration at the conclusion of the observation period. Haptoglobin concentrations were determined in each designated serum sample by use of a commercially available colorimetric assay in accordance with the manufacturer’s instructions. The optical density of each well was determined by a microplate reader with a wavelength of 615 nm. Each sample was assayed in duplicate, and the mean result was calculated and used for analysis. The manufacturer-stated lower limit of detection for haptoglobin in that multispecies assay is 0.005 mg/mL.

**VN**

A standard VN microtiter assay was used to detect antibodies against BVDV in serum samples obtained on days 0 and 28. The reference strain used for the assay was the noncytopathic BVDV strain used for experimental inoculation. Each sample was heat inactivated at 56°C for 30 minutes, and then serial 2-fold dilutions (1:4 to 1:2,048) were prepared with 50 µL of MEM in triplicate in wells of a 96-well plate. To each well, 50 µL of MEM that contained 100 TCID₅₀ of the reference BVDV strain was added. The plate was incubated for 1 hour at 38.5°C in humidified air that contained 5% CO₂. Then, 2.5 X 10⁴ MDBC cells in 50 µL of MEM were added to each well. The plate was incubated for 72 hours at 8.5°C in humidified air that contained 5% CO₂. The resulting cell monolayers underwent an immunoperoxidase staining method so that VN could be visually detected. For each sample, the anti-BVDV antibody titer was determined as the greatest dilution at which at least 2 of the 3 wells were free of immunoperoxidase staining.

**VI**

Isolation of BVDV was performed on blood samples collected into evacuated tubes that contained sodium EDTA on days 0, 7, 14, 21, and 28. Blood samples underwent hypotonic lysis of RBCs to yield the WBC fraction. The isolated WBCs were resuspended in EMEM supplemented with 10% equine serum, l-glutamine (200mM), penicillin G (100 U/mL), and streptomycin (100 µg/mL) and cocultivated in 25-cm² flasks that contained a monolayer of MDBC cells for 5 days at 37°C in humidified air that contained 5% CO₂. Following cocultivation, 50 µL of the cell culture supernatant was inoculated into each of 3 wells of a 96-well microtiter plate that contained a monolayer of MDBC cells in EMEM with 10% equine serum and antimicro-
bials. The plate was incubated for 3 days at 37°C in humidified air that contained 5% CO₂. Then the cells in each well were stained with an immunoperoxidase staining method so that cells infected with noncytopathic BVDV could be visually identified.

Data analysis

Descriptive data were generated to summarize CIS, VI, and VN findings. Generalized linear mixed models were used to compare rectal temperature, WBC count, neutrophil count, lymphocyte count, and serum haptoglobin, fibrinogen, and iron concentrations between the BVDV and control groups. In each of those models, treatment group (BVDV or control), sample acquisition time (time), and the interaction between treatment group and time were included as fixed effects and calf identification was Included as a random effect to account for repeated measures on each calf. Models were fitted for each of the most likely residual covariance structures (unstructured and first-order autoregressive) and compared by use of the corrected Akaike information criterion. The residual covariance structure that resulted in the lowest Akaike information criterion value was used for all subsequent modeling for a given outcome. For all models, the interaction between treatment group and time was significant; therefore, comparisons were made between the 2 treatment groups at each time.

Throughout the 7-day acclimation period (baseline) and 35-day observation period, the activity of each calf was categorized as lying, walking, or standing on the basis of data obtained from the accelerometer. For each day, the cumulative times each calf spent lying, walking, and standing were calculated. The mean cumulative time spent on each activity daily was then calculated for the calves in each group. Data for calves with extreme values for any activity (lying, walking, or standing) during baseline were excluded from subsequent analyses. Extreme values were defined as those that were >3 SDs from the mean for the remaining calves in that treatment group.

For each day during the observation period (days 0 through 35), the cumulative times calves spent lying, walking, and standing were converted to ratios. The respective mean baseline value was used as the denominator for each of those ratios. Therefore, a ratio >1 indicated that the time spent on a particular activity during a given day was greater than the time spent on that activity at baseline, and a ratio <1 indicated that the time spent on a particular activity during a given day was less than the time spent on that activity at baseline.

Generalized linear mixed models with a lognormal distribution function were used to compare rectal temperature and the hematologic and biochemical variables. Because the generalized linear mixed model tests whether a given mean differs significantly from 0 and the natural logarithm of 1 equals 0, the model effectively assessed whether the activity on a given day differed significantly from that at baseline. The interaction between treatment group and time was significant for all models; thus, comparisons were made between the 2 treatment groups for each day of the observation period. The resultant least squares mean values and associated 95% confidence intervals were transformed back to the original scale for reporting purposes. All analyses were performed with commercially available statistical software, and values of $P < 0.05$ were considered significant.

Results

CISs and physical examination findings

During the acclimation period (days –7 to –1; baseline), none of the calves in the BVDV group were assigned a CIS >1. However, 2 calves in the control group were assigned a CIS of 2 (slight illness) on days –3 and –2.

Of the 10 calves in the BVDV group, a CIS of 2 was assigned to 4 calves on days 8 through 12, 1 calf on day 14, 3 calves on day 17, and 2 calves on day 25. Of the 10 calves in the control group, a CIS of 2 was assigned to 2 calves on day 15 and 1 calf on day 16. A CIS ≥3 was not assigned to any calf during the study, and none of the calves required treatment during the 35-day observation period. The mean rectal temperature for calves in the BVDV group was significantly ($P = 0.002$) greater than that for calves in the control group on days 7 and 28.

One calf in the BVDV group was mildly lame on days –3, 0, and 1. The data from that calf were included in all analyses. Three additional calves in the BVDV group became lame in the right hind limb after experimental inoculation, presumably because of skin lesions associated with the accelerometer. Each of those calves was assigned a lameness score on a scale of 1 to 5 as described. One calf became lame on day 6 and was assigned a lameness score of 2; however, that lameness resolved by day 7. Another calf was assigned a lameness score of 2 on days 8, 9, and 20. The behavioral data for those 2 calves were retained in all analyses. The third calf had lameness that persisted from days 8 to 21 and was assigned a lameness score that varied from 2 (mild lameness) to 3 (moderately lame) during that period. It developed substantial skin lesions on the right hind limb that were associated with accelerometer placement. The addition of extra padding around the accelerometer unit did not result in a favorable response, and the accelerometer was removed from the calf on day 21. The behavioral data from this calf were not included in any of the analyses.

Clinicopathologic variables

Outcomes were compared between the treatment groups for each day of the observation period (days 0 through 35) because there was a significant
interaction between treatment group and time. The mean WBC count for calves in the BVDV group was significantly ($P \leq 0.035$) lower than that for calves in the control group on days 7 and 14, and mean lymphocyte and neutrophil counts for calves in the BVDV group were significantly ($P < 0.05$) lower than those for calves in the control group on day 7 (Figure 1). The mean serum haptoglobin, fibrinogen, and iron concentrations did not differ significantly between the BVDV and control groups at any time after experimental inoculation.

**VI and VN**

All 20 study calves had negative results for BVDV on VI and were seronegative for antibodies against BVDV on day 0. All 10 calves in the control group had negative results for BVDV on VI and remained seronegative for anti-BVDV antibodies throughout the 35-day observation period. For the 10 calves in the BVDV group, BVDV was isolated from all 10 calves on day 7, 4 calves on day 14, and 1 calf on day 21. All 10 calves in the BVDV group had serum neutralizing antibodies against BVDV on day 28.

**Behavioral data**

The baseline standing and walking data for 1 calf in the BVDV group and the baseline walking data for 2 calves in the control group were removed from the analysis because the values were $> 3$ SDs from the respective means for those activities for their respective treatment groups. The baseline lying data for the calf in the BVDV group and the baseline lying and standing data for the 2 calves in the control group were retained in the analysis. The data for the calves that developed lameness following experimental inoculation were retained in the analysis except for the data for the calf that developed severe skin lesions on the right hind limb that necessitated removal of the accelerometer.

The mean times calves in each group spent lying, walking, and standing following experimental inoculation on day 0 varied, compared with those times during the baseline period, and often differed by treatment group and study day. Following experimental inoculation, the calves in the BVDV group generally spent less time walking and more time lying, compared with the times they spent walking and lying during baseline, whereas the calves in the control group generally spent less time standing and walking and more time lying, compared with the times they spent standing, walking, and lying during baseline. Specifically, compared with baseline values, the calves in the BVDV group spent significantly more time lying on days 3 ($P = 0.037$) and 8 ($P = 0.003$), less time walking on days 8 ($P = 0.025$) and 9 ($P = 0.013$), less time standing ($P = 0.001$) on day 8, and more time standing on days 14 ($P = 0.026$), 26 ($P = 0.025$), and 27 ($P = 0.026$; Figure 2). The calves in the control group spent significantly less time standing on days 4 ($P = 0.005$) and 15 ($P = 0.027$), less time walking on days 8 through 12 ($P < 0.02$ for all days), and more time lying down on days 1, 4, 5, and 15 ($P < 0.02$ for all days), compared with the corresponding baseline values. The mean time allocated to each activity (lying, walking, and standing) did not differ significantly between the BVDV and control groups on any day except day 8, when calves in the BVDV group spent significantly ($P = 0.001$) less time standing than the calves in the control group.

**Discussion**

The main objective of the present study was to assess the use of 3-D accelerometers to monitor behavioral changes in cattle with subclinical disease induced by experimental infection with a low-virulent strain of BVDV. We evaluated behavioral responses in conjunction with traditional markers of inflammation to further refine the effect of BVDV infection on cat-
tle behavior and validate the use of remote monitoring devices to detect subtle changes in the behavior of cattle with subclinical disease. To our knowledge, the present study was the first to evaluate behavioral changes in cattle acutely infected with BVDV by the use of objective remote monitoring technology.

Prior to experimental inoculation on day 0 in the present study, the CISs and daily activity for all calves, including those assigned to the BVDV group, were as expected for healthy calves. Additionally, all calves had negative results for BVDV on VI and were seronegative for antibodies against BVDV prior to inoculation. Those findings suggested that the calves were healthy and had not been exposed to and were not infected with BVDV before day 0. All the control calves had negative results for BVDV on VI and remained seronegative for antibodies against BVDV throughout the study period; this fact indicated that those calves were not inadvertently exposed to BVDV. The calves inoculated with the low-virulent BVDV type 2 strain 134F developed only subclinical or mild clinical disease, mild clinicopathologic alterations, and subtle behavioral changes. All the calves in the BVDV group were viremic on day 7 (7 days after BVDV inoculation). However, clinical disease as determined by subjective assessment (ie, CIS > 1) was not detected until day 8, and then it was only detected in less than half (4/10) of the BVDV-infected calves. Clinical disease in those calves was characterized by mild signs of depression and developed shortly after the onset of viremia, which suggested that the low-virulent strain of BVDV used to inoculate those calves caused an acute-phase response as expected. Calves experimentally infected by BVDV strains with moderate to high virulence typically develop transient pyrexia 48 to 72 hours after infection and then develop persistent and marked pyrexia 6 to 8 days after infection, which is accompanied by clinical signs of depression, anorexia, weakness, and diarrhea.3,9

Results of other studies11,29 indicate that subjective measures such as CISs lack diagnostic sensitivity for the detection of diseased cattle, and the results of the present study supported those findings. Only 4 of the 10 BVDV-infected calves that were viremic on day 7 were assigned a CIS of 2; the remaining 6 calves were assigned a CIS of 1 (ie, clinically normal). The BVDV-infected calves that were viremic on days 14 (n = 4) and 21 (1) were all assigned a CIS of 1 and were not subjectively ill. Moreover, a CIS of 2 was assigned to 2 control calves on day 14 and 1 control calf on day 16. None of the calves in either group required medical treatment. Statistical comparison of the CISs between the BVDV and control groups was not performed because the investigator who assigned the CISs was not blinded to treatment group assignment for biosecurity purposes. Calves were visually assessed only once daily to minimize the effect of human observation on their behavior, which might have limited the investigator’s ability to readily detect subtle changes in their clinical appearance.

The calves in the BVDV group had a significantly greater mean rectal temperature and lower WBC, neutrophil, and lymphocyte counts, compared with those for the calves in the control group, on day 7. Those were expected changes for calves acutely infected with BVDV. Cattle acutely infected with BVDV typically have a significant decrease in the WBC count between 6 and 12 days after infection9; however, in some cattle, that decrease in WBC count may be detectable.

Figure 2—Ratio of the mean time spent lying (A), walking (B), or standing (C) daily after experimental inoculation (day 0) to the mean time spent lying, walking, or standing during the 7 days before experimental inoculation (days –7 to –1; baseline) for the calves of the BVDV (dotted line) and control (solid line) groups of Figure 1. The brackets delimit the range for each ratio on a given day. The accelerometer was removed from 1 calf in the BVDV group on day 21 because of skin lesions and lameness, and the behavioral data from that calf were excluded from all analyses. Therefore, the values for the BVDV group represent the means for 9 calves. a Within a day, the mean time spent on the given behavior differs significantly (P < 0.05) from baseline for the control group. b Within a day, the mean time spent on the given behavior differs significantly (P < 0.05) from baseline for the BVDV group. c Within a day, the ratio for the BVDV group differs significantly (P < 0.05) from that for the control group. See Figure 1 for remainder of key.
as early as 3 days after infection. Because the calves were inoculated with a low-virulent strain of BVDV, the magnitudes of those alterations were not as great as those observed in calves infected with more virulent strains of BVDV.

In the present study, the mean serum concentrations of iron and the acute-phase proteins haptoglobin and fibrinogen did not differ significantly between the BVDV and control groups. These findings were in contrast to results of another study in which the mean haptoglobin concentration for calves experimentally inoculated with BVDV was significantly increased from the preinoculation concentration beginning 4 to 8 days after inoculation, peaked between 8.5 and 9.5 days after inoculation, and returned to approximately the preinoculation concentration 15 days after inoculation. In that study, the mean fibrinogen concentration peaked between 8 and 9 days after inoculation and returned to approximately the preinoculation concentration by 15 days after inoculation. In yet another study, the mean haptoglobin concentration did not increase significantly for calves experimentally exposed to BVDV. The BVDV strain used to inoculate the calves of the present study may not have been virulent enough to stimulate production of haptoglobin and fibrinogen; however, the significant decrease in the WBC count observed for the calves in the BVDV group would seem to contradict the idea that the strain used did not cause a detectable acute-phase response. It is more likely that the timing of blood sample collection at 7 and 14 days after experimental inoculation prevented us from detecting an increase in acute-phase protein concentrations. Regardless, monitoring acute-phase protein concentrations in calves at 7-day intervals after experimental inoculation with a low-virulent strain of BVDV was not useful for the identification of calves with mild disease.

The use of remote monitoring devices, such as the accelerometers used in the present study, that continuously collect individual animal data would obviate the need to predict appropriate times for sample collection and the handling of cattle for invasive and costly procedures. The objective data obtained by those devices might be more sensitive for the detection of diseased cattle than subjective visual observation by human caretakers and may also be able to predict the onset of disease, particularly for cattle with mild or subclinical infections.

The calves in the BVDV group spent significantly more time lying daily after being experimentally inoculated than they did prior to inoculation. Those findings were similar to results of other studies that indicate remote monitoring devices can detect changes in the behavior of cattle following exposure to respiratory tract pathogens. Beef steers instrumented with accelerometers and pedometers that were experimentally inoculated with Mannheimia haemolytica spent a greater proportion of their time lying and walked fewer steps daily 4 days after inoculation, compared with the time spent lying and number of steps walked daily prior to inoculation. Although there was no correlation between the behavioral data obtained by the remote monitoring devices and disease severity in that study, the results indicate that behavioral changes associated with BRD can be detected with accelerometers. In another study, beef calves were instrumented with accelerometers and pedometers and then experimentally inoculated with Mycoplasma bovis intranasally. The time the calves spent at specific areas of the pen (waterer, feed bunk, and shelter) and the number of steps walked each day were compared before and after inoculation. The results of that study indicate that CIs were associated with the time spent at specific areas of the pen and the distance traveled, and alteration of behavior is significantly associated with disease severity.

In the present study, behavioral changes were detected for calves in both the BVDV and control groups after experimental inoculation. Overall, calves in both groups spent more time lying and less time walking and standing after inoculation, compared with the times spent lying, walking, and standing during baseline. The low-virulent BVDV strain used to inoculate calves in the BVDV group induced only mild disease, which likely contributed to our inability to identify significant differences in behavior between the calves in the BVDV and control groups. Investigation of cattle infected with more virulent strains of BVDV is warranted to better refine the capabilities of accelerometers to detect BVDV-infected cattle that are ill.

Difficulty in the identification of contrasting behavioral changes between calves in the BVDV and control groups was further compounded by the necessity to house the BVDV-infected calves separately from the control calves in biosecure pastures because of the infectious nature of BVDV. Although the size and topography of the 2 pastures used to house the 2 groups were approximately equal, they were not identical, and this could have confounded the behavioral indices.

Even though the accelerometers used in the present study were easily applied and well tolerated by most of the study calves, they were associated with substantial skin lesions and lameness in some calves. In fact, 1 calf had to be removed from the study on day 21 because of the severity of the skin lesions. Lameness will alter an animal’s behavior and limit the usefulness of remote monitoring devices for detection of clinically ill cattle. Consequently, it is recommended that changes be made to the fastening mechanism of this specific accelerometer model if it is to be used in a commercial setting for long-term data acquisition from light-weight cattle in environments with high humidity and ambient temperatures. Our laboratory group has found more ergonomic devices that are commercially available and well tolerated by both young calves and adult cattle; however, the data acquisition capabilities of those devices differ from those of the accelerometers used in the present study.

Results of the present study indicated that data obtained by 3-D accelerometers may be useful for the detection of behavioral changes in cattle acutely infected with BVDV, even those with only mild disease.
Objective data that are continuously obtained in real time might be able to identify diseased cattle sooner than subjective CFSs and traditional markers of inflammation such as acute-phase protein concentrations.

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Footnotes
b. G’Power, version 3.1.9.2, Heinrich Heine University Düsseldorf, Düsseldorf, Germany.
c. GPI Programmable Accelerometer, Reference LLC, Elkader, Iowa.
d. Insightful Miner, Insightful Corp, Seattle, Wash.
e. Gibco Life Technologies Corp, Grand Island, NY.
f. Hyclone, GE Healthcare Life Sciences, Logan, Utah.
g. Phase Haptoglobin Assay, Tridelta Development Ltd, Maynooth, County Kildare, Ireland.
h. SAS, version 9.2, SAS Institute Inc, Cary, NC.

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