Prevalence and lameness-associated risk factors in Alberta feedlot cattle

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ABSTRACT: Lameness in cattle is a health and welfare concern; however, limited information is available on risk factors and the relationship between lameness and common diseases like bovine respiratory disease (BRD). Therefore, the objectives of this study were to: 1) identify prevalence of lameness in feedlot cattle and related risk factors of cattle diagnosed as lame; and 2) determine associations between BRD occurrence and lameness. Feedlot cattle health records were available from 28 feedlots for 10 yr. The data set consisted of 663,838 cattle records, with 13.9% (92,156) diagnosed with a disease, including 32.3%, 46.0%, and 22.0% with lameness, BRD, and other diagnoses, respectively. Lameness was classified into four categories: foot rot (FR), joint infections (JI), lame with no visible swelling (LNVS), and injuries (INJ), with a prevalence of 74.5%, 16.1%, 6.1%, and 3.1%, respectively. Lameness was compared across cattle types (arrival date and weight) as well as age classification (calf vs. yearling), gender (steer vs. heifer), and season of placement in the feedlot (spring, summer, fall, and winter). Within the disease-diagnosed population, lameness represented 28.5% of treated fall-placed calves, 38.5% of winter-placed calves, and 40.8% of treated yearlings. Foot rot was the most common diagnosis with 74.5% of all lameness diagnoses, with winter- and fall-placed calves more likely to be diagnosed with FR compared to yearlings (OR: 1.19, 95% CI: 1.10–1.30 and OR: 1.46, 95% CI: 1.38–1.55, respectively). Joint infections were the second most common diagnosis (16.1%). Compared to yearlings, fall-placed calves had a higher odds (OR: 3.64, 95% CI: 3.12–4.24) for JI. Injuries and LNVS were the least common but again fall-placed calves had higher odds of this diagnosis compared to yearlings (OR: 2.26, 95% CI: 1.70–2.99 and OR: 9.10, 95% CI: 6.26–13.2, respectively). Gender was significantly different for JI as steers were less likely affected compared to heifers (OR: 0.687, 95% CI: 0.545–0.867), and more likely affected by LNVS (OR: 2.46, 95% CI: 1.57–3.84). Of all lameness-associated deaths, JI accounted for almost 50%. Finally, cattle diagnosed with BRD were subsequently more likely to be diagnosed with INJ, JI, or LNVS (P < 0.001 for all comparisons). In conclusion, animal type and gender were associated with type of lameness diagnoses, allowing feedlots to allocate resources to groups at highest risk and focus on early intervention strategies.

Key words: beef cattle, foot rot, lameness diagnosis, occurrence

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INTRODUCTION

Lameness in feedlot cattle is a major health and welfare concern (Griffin et al., 1993; Marti et al., 2016). Negative impacts from lameness

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include reductions in feed and water intake, body condition score (BCS), and immune response, as well as pain, discomfort, and stress (Desrochers et al., 2001). In a previous study of feedlot cattle, foot diseases accounted for 70% of all lameness cases, whereas 15%, 12%, and 3% were attributed to upper-body injuries, septic joints, and swollen injection sites, respectively (Griffin et al., 1993). The etiology of lameness is often multifactorial and may include environmental and animal-based risk factors. For example, environmental factors could include weather conditions, e.g., precipitation, which can compromise the skin barrier of the foot, predisposing it to infections such as foot rot and (inter-) digital dermatitis (Tibbetts et al., 2006; Wilson-Welder et al., 2015). Also, standing in muddy and wet areas of a pen can increase risk of foot rot (Stokka et al., 2001). Animal-based factors, e.g., sex differences based on more rapid weight gain in steers vs. heifers, may also increase susceptibility to lameness (Zinn et al., 2008).

The transition between a ranch and feedlot is a challenging time for cattle, as they are exposed to multiple stressors including handling, transportation, commingling, in addition to changes in feed, water, and housing; all of these can result in immune suppression and increase the risk of illness such as bovine respiratory disease (BRD; Hodgins et al., 2002). Cattle with BRD are clinically recognized by altered behavior, including reduced social interactions, movement, and reduced time spent consuming feed and water (White et al., 2012). We hypothesized that compromised immunity as well as this altered, BRD-related behavior can result in an increased chance of lameness due to avoiding normal social interactions and separation in less favorable areas of the pen. Another interaction between occurrence of BRD and lameness is Mycoplasmosis, as it can lead to pneumonia as well as joint infections (Maunsell et al., 2011). Consequently, our objectives were 1) to identify the prevalence of lameness and related risk factors in feedlot cattle as related to animal type (age category calf or yearling) and gender (steers and heifers) and 2) to investigate associations between BRD occurrence and risk for development of lameness.

MATERIALS AND METHODS

This study used data from 28 finishing feedlots in southern Alberta (Table 1). Cattle in these feedlots were housed in outdoor pens with a dirt surface and wind protection, with access to a water source and stepwise, grain-based diets placed in feed bunks, as is common in Alberta feedlots (Hunt, 2007). Feedlot health records were provided by Veterinary Agri-Health Services (VAHS) from Airdrie, Alberta, Canada and were collected chuteside by feedlot workers and entered electronically into Medlogic software (VAHS, Airdrie, Alberta, Canada). Records were available for a 10-yr interval using the same software (2005 to 2015). Health records included the following clinical lameness categories: foot rot (FR), foot rot in heavy cattle (>363 kg at treatment as per veterinary protocol), injury (INJ), lame with no visible swelling which was added as a new category within the Medlogic software as of January 1, 2009 (LNVS), and joint infection (JI). Although all other disease diagnoses were recorded, this study only focused on the disease category BRD and all other disease diagnoses were categorized as "other."

For each animal in the feedlot, information was available on animal ID, feedlot identification, arrival date, arrival weight, cattle type (calves and yearlings), gender (steer or heifer), and animal deaths. Cattle types were categorized by season of arrival in the feedlot, age, and gender: fall (steer and heifer calves), winter (steer and heifer calves), yearling (steers and heifers), breeding (cows, breeding heifers, bulls, and bull calves), and other (dairy calves and natural beef), where natural beef was defined as cattle not administered hormones or antimicrobials during the feeding program. For cattle diagnosed as sick by feedlot personnel, additional information recorded included diagnosis, treatment date, weight at treatment, and type of treatment that are presented separately in Supplementary Appendix 1.

Data Cleaning

Exact duplicates of cattle health records were omitted. As the records were used for recording of treatments, only the first observation of a case was retained in the data set to study associations between disease events (N = 96,674). The majority of cattle at these feedlots were calves and yearlings; therefore, the category "breeding" or "other" cattle types were omitted as well as unlikely observations for body weight (Fig. 1). Also, in the complete data set, observations of number of days between BRD and lameness ranged from 0 to 1,410 d (median, 18). However, to test the hypothesis if both disease occurrences were correlated, a range was chosen of 0 to a maximum of 60 d (Taylor et al., 2010), and more extended time intervals between the disease observations omitted from the analyses. A single feedlot contributed 45.7% of the treatment records.

Table 1. Disease-diagnosed cattle, with number of lameness cases in parenthesis and percentage of lameness cases (N = 29,755 treated lame cases) per feedlot with annual capacity

Feedlot	Annual feedlot Capacity (× 10^3)	Diagnosed diseased (diagnosed lame; *n*, %)	Foot rot *N* (%)	Injury *N* (%)	Joint infection *N* (%)	Lame—no visible swelling *N* (%)
1	0.80	16 (3, 19)	3 (19)	–	–	–
2	1	85 (19, 22)	–	2 (2)	15 (18)	2 (2)
3	1.2	595 (266, 44)	220 (37)	2 (0.3)	28 (5)	16 (3)
4	1.2	58 (17, 29)	10 (17)	–	2 (3)	5 (9)
5	1.8	1,234 (432, 35)	219 (18)	15 (1)	103 (8)	95 (8)
6	2.0	2,566 (816, 31)	347 (14)	34 (1)	301 (12)	134 (5)
7	2	835 (356, 42)	202 (24)	6 (0.7)	28 (3)	120 (14)
8	2.5	1,207 (247, 20)	234 (19)	2 (0.08)	11 (0.9)	–
9	2.5	615 (33, 5.3)	–	1 (0.2)	32 (5)	–
10	2.5	146 (2, 1.3)	1 (0.7)	–	1 (0.7)	–
11	2.5	335 (30, 8.9)	16 (5)	2 (0.6)	12 (4)	–
12	2.5	1,090 (395, 36)	183 (17)	48 (4)	145 (13)	19 (0.2)
13	2.5	181 (51, 28)	5 (3)	5 (3)	31 (17)	10 (6)
14	2.5	217 (49, 22)	46 (21)	1 (0.5)	2 (0.9)	–
15	3	3,258 (756, 23)	406 (12)	4 (0.1)	106 (3)	240 (7)
16	3.5	1,594 (716, 44)	601 (38)	3 (0.2)	88 (6)	24 (1)
17	3.5	91 (2, 2.1)	2 (2)	–	–	–
18	4.0	4,612 (1,554, 33)	1,169 (25)	66 (1)	286 (6)	33 (0.7)
19	4.5	536 (140, 26)	85 (16)	33 (6)	18 (3)	4 (0.7)
20	5.0	2,178 (375, 17)	12 (0.6)	3 (0.1)	244 (11)	116 (5)
21	5	4,938 (1,836, 37)	1,593 (32)	14 (0.3)	148 (3)	81 (2)
22	5.5	1,832 (468, 25)	258 (14)	51 (3)	9 (0.5)	150 (8)
23	7.5	4,992 (2,344, 46)	2,008 (40)	35 (0.7)	264 (5)	37 (0.7)
24	8	3,117 (604, 19)	229 (7)	36 (1)	247 (8)	92 (3)
25	9	1,846 (531, 28)	479 (26)	7 (0.4)	35 (2)	10 (0.5)
26	17	5,482 (2,066, 37)	1,399 (26)	120 (2)	382 (7)	165 (3)
27	17	6,346 (1,547, 24)	1,050 (17)	44 (0.7)	453 (7)	–
28	20	42,154 (14,100, 33)	11,402 (27)	404 (1)	1,828 (4)	466 (1)
Total	140,000	92,156 (29,755,32.3)	22,179 (24)	938 (1)	4,819 (5)	1,819 (2)

Analysis of data without inclusion of this feedlot did not alter the results and therefore analyses are presented of the full data set.

Data Management

Data were compiled in a commercial spreadsheet software program (Microsoft Excel, v.15; Microsoft Corporation, Redmond, WA). In the data set, a case was defined as an animal diagnosed and treated for one of six disease categories; FR, INJ, LNVS, JI, BRD, and other, respectively. Two lameness categories, foot rot and foot rot in heavy cattle, were combined into one category (FR), as it was the same diagnosis and only differed in recommended treatment due to days on feed (DOF) at occurrence and withdrawal time of the drugs recommended. Treatment dates in the data set were collapsed into the following seasons: spring (March 20 to June 20), summer (June 21 to September 21), fall (September 22 to December 20), and winter (December 21 to March 19). A categorical variable (treatment weight) was created using quartiles for classification of weight into four categories; 136 to 264 kg, 265 to 335 kg, 336 to 455 kg, and 456 to 936 kg.

Statistical Analyses

All statistical analyses were performed using Stata (Ver. 14; StataCorp LP, College Station, TX). Descriptive statistics are presented as total N, %, median DOF, and treatment weight. Comparisons for DOF and treatment weight were made using t-tests within fall-placed and yearling animals as well as within gender (steer vs. heifer). The following statistical steps for model building were the same for all diagnoses. Multicollinearity was assessed between each predictor variable and separate outcomes of interest, namely FR, INJ, JI, and LNVS. If multicollinearity was present, the predictor variable with the fewest missing observations was chosen. Also,

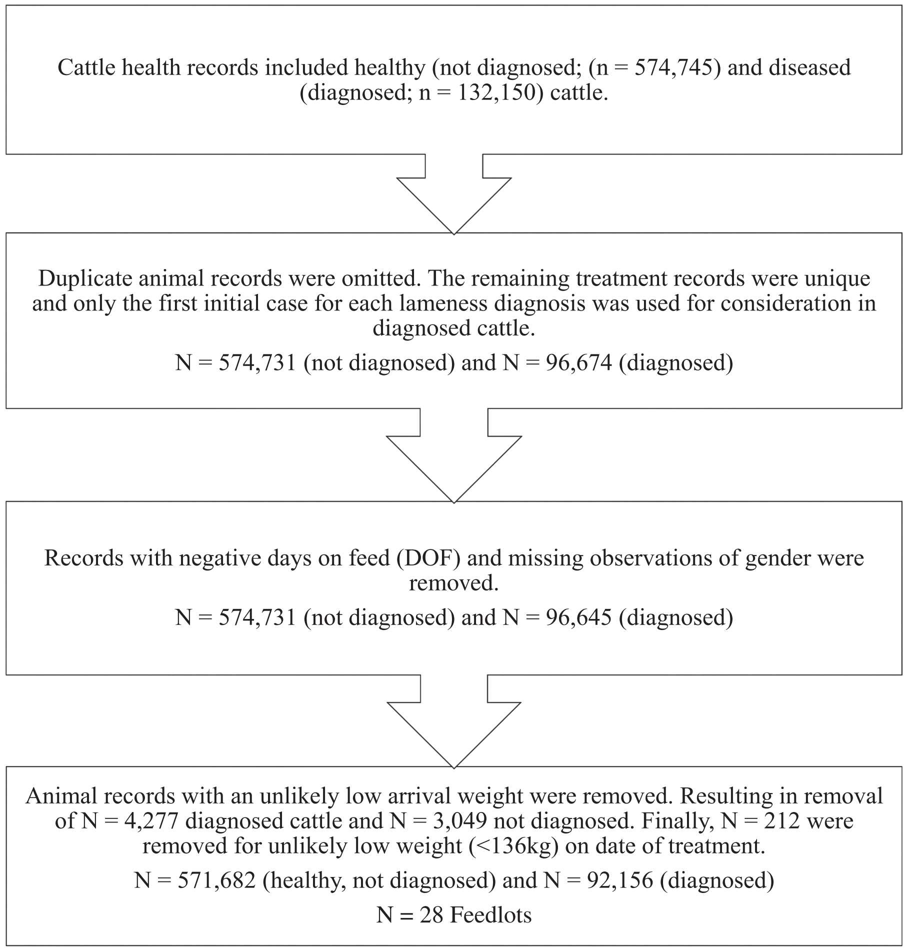

Figure 1. Flow chart diagram illustrating data management and cleaning of cattle health records used in this study.

the year of the observation had no impact on the model outcomes and was therefore not considered as variable in the models. Univariate analysis was done to determine the association between an individual outcome of interest (FR, INJ, JI, LNVS) and each predictor variable (animal type, gender, season of placement) and within the diseased population for season of treatment, weight, and DOF. Predictor variables with an association $P < 0.25$ were considered for the regression models. Next, remaining predictor variables in each model outcome were analyzed in separate random-effects multilevel mixed logistics regression models (XTMELOGIT or MELOGIT in Stata). The variable feedlot was forced into the model as a random effect to eliminate the variance by feedlot. However, there was no impact of choosing random or fixed effects; implying feedlot ID did not impact the outcome of specific lameness diagnoses. Finally, backward variable elimination was performed. Modification was assessed using a likelihood-ratio test. If effect of a modification (e.g., animal type and gender, and DOF and gender) was significant ($P < 0.05$) in the four separate lameness outcome models, they remained in the model. Significant variables ($P < 0.05$) remained in the final model. The best final model was assessed using a goodness-of-fit test. In addition to significant variables, if confounding was present (i.e., removal of any variable resulted in a ≥20% change in the estimate of any other significant predictor), that variable was also retained in the model.

RESULTS

Prevalence and General Characteristics of Lameness Occurrence

The data set analyzed consisted of $N = 663{,}838$ cattle records. Of all recorded observations, 13.9% (92,156/663,838) of cattle were diagnosed with a disease of which 32.3% were diagnosed with lameness (29,755/92,156) (Table 1), resulting in a prevalence estimation of 4.5%. Of the remaining diagnosed animals, 46.0% were diagnosed with BRD (42,205/92,156), and 22.0% with another diagnosis (20,196/92,156).

The prevalence of lameness in all 28 feedlots ranged between 1.3% and 46% over the 10-yr

Table 2. Total number of cases (percentages) of lameness and by lameness diagnosis, and BRD, total diagnosed, and total overall in data collected from 28 feedlots by type, gender, and cattle deaths (N = 92,156 treated cases and N = 663,838 cases in data set)

	Type		Gender		Type × gender				
Variable	Calves	Yearling	Steer	Heifer	Steer calves	Heifer calves	Yearling steers	Yearling heifers	Deaths
Total lame	20,587 (4.9)	8,210 (4.0)	19,590 (4.4)	10,165 (4.7)	13,712 (4.5)	6,875 (5.8)	5,497 (4.2)	2,713 (3.6)	1,163 (12.8)
Foot rot	14,346 (3.4)	7,100 (3.4)	14,270 (3.2)	7,909 (3.6)	9,238 (3.0)	5,108 (4.3)	4,794 (3.7)	2,306 (3.0)	351 (3.9)
Injury	664 (0.2)	229 (0.1)	674 (0.2)	264 (0.1)	489 (0.2)	175 (0.1)	158 (0.1)	71 (0.1)	122 (1.3)
Joint infection	3,976 (0.9)	721 (0.4)	3,361 (0.8)	1,458 (0.7)	2,810 (0.9)	1,166 (1.0)	484 (0.4)	237 (0.3)	577 (6.4)
Lame—no swelling	1,601 (0.4)	160 (0.1)	1,285 (0.3)	534 (0.2)	1,175 (0.4)	426 (0.4)	61 (0.004)	99 (0.1)	113 (1.2)
BRD	34,967 (8.3)	6,285 (3.1)	29,261 (6.6)	12,944 (5.9)	24,625 (8.1)	10,342 (8.8)	4,109 (3.2)	2,176 (2.9)	2,688 (29.7)
Total diagnosed	69,359 (16.4)	20,120 (9.8)	63,116 (14.1)	29,040 (13.3)	48,174 (15.8)	21,185 (18.0)	13,626 (10.5)	6,494 (8.6)	5,890 (65.0)
Total present	421,664 (100)	205,838 (100)	446,064 (100)	217,774 (100)	304,140 (100)	117,524 (100)	129,937 (100)	75,901 (100)	9,059 (100)

interval (Table 1). There was greater variation in the prevalence of lameness between feedlots then within a feedlot.

In Table 2 lameness diagnoses are presented per gender and type of animal, showing 4.4% of steers and 4.7% of heifers were affected by lameness (Table 2). Fall-placed calves represented 17.3% of cattle diagnosed with any disease, and of those diagnosed 28.5% were classified with lameness. Winter-placed calves represented 11.5% of all diagnosed animals, of those 38.5% lameness and finally, yearling cattle 9.7% diagnosed sick, but of those 40.8% with lameness. Of cattle that died in the feedlots, 65.0% had been previously diagnosed with a disease. Of the disease-diagnosed cattle, 19.7% were diagnosed with lameness prior to death (Table 2).

Of all animals that were ultimately diagnosed with lameness, 40% were winter-/spring-placed. Foot rot was the most prevalent lameness diagnosis with 74.5% of all recorded lameness. The majority of FR diagnoses were treated during spring/summer (Table 3). The INJ diagnosis was the least frequent cause of lameness in all animals at 3.1%. Of all fall-placed calves, 3.3% of all lameness cases were INJ, compared to 3.0% of winter-placed calves and 2.8% of yearlings. Cattle diagnosed with INJ had the second lowest number of all deaths after initial lameness diagnosis (10.4%).

Joint infections were the second most common lameness diagnosis (16.1%). Of all cattle diagnosed with JI, 17.2% were steers and 14.3% were heifers. Furthermore, 73.0% of all JI cases occurred in fall-placed calves compared to 8.0% in winter-placed calves. In addition, 20.2% of all lameness cases in fall-placed calves were JI, compared to 14.3% and 8.8% in winter-placed and yearling cattle, respectively. Death due to JI accounted for 49.6% of all lameness-diagnosed deaths (Table 2). Finally, cattle with LNVS were recorded in 6.1% of all lameness diagnoses, of which 6.6% affected steers and 5.3% affected heifers. Fall-placed calves were the most common cattle type affected with LNVS as compared to yearling cattle. However, of all lameness diagnoses, 8.8% of fall-placed cattle were diagnosed with LNVS, whereas animals placed in other seasons were only affected by 1.8%, 1.9%, and 6.3% respectively. Cattle diagnosed with LNVS had the lowest recorded deaths of all cattle diagnosed as lame (Table 2). Lastly, fall was the most common season of treatment for cattle diagnosed with LNVS (Table 3).

The relationship of DOF at treatment and treatment weight is presented in Table 4. Most

Table 3. Total number of cases (percentages of total number diagnosed sick) for lameness and per lameness and BRD diagnoses, collected from 28 feedlots by season of placement and season of treatment ($N = 92,156$ treated cases)

	Season of placement		Season of treatment			
Variable	Winter/spring	Summer/fall	Winter	Spring	Summer	Fall
Total lame	7,681 (40.1)	22,074 (30.2)	5,605 (29.0)	13,230 (63.7)	3,399 (51.7)	7,521 (16.5)
Foot rot	6,488 (33.9)	15,691 (21.5)	3,444 (17.8)	12,341 (59.4)	2,949 (44.8)	3,445 (7.6)
Injury	228 (1.2)	710 (1.0)	260 (1.3)	203 (1.0)	113 (1.7)	362 (0.8)
Joint	842 (4.4)	3,977 (5.4)	1,550 (8.0)	616 (3.0)	285 (4.3)	2,368 (5.2)
Lame—no swelling	123 (0.6)	1,696 (2.3)	351 (1.8)	70 (0.3)	52 (0.8)	1,346 (3.0)
BRD	6,481 (33.8)	35,274 (48.3)	7,683 (39.8)	3,540 (17.0)	1,022 (15.5)	29,960 (65.9)
Total diagnosed	19,150	73,006	19,326	20,770	6,579	45,481

Table 4. Days on feed (DOF; median d) and treatment weight (median kg) of cattle diagnosed with lameness or BRD stratified by cattle type

	DOF at treatment (median d)				Treatment weight (median kg)			
Variable	Steer calves	Heifer calves	Yearling steers	Yearling heifers	Steer calves	Heifer calves	Yearling steers	Yearling heifers
Lameness								
Foot rot	159	167	58	62	497	470	508	489
Injury	48	62	49	39	318	307	465	411
Joint	38	42	50	30	285	272	455	426
Lame—no swelling	26	25	61	19	272	267	445	406
BRD	17	17	20	13	286	263	424	410

importantly, both heifer and steer calves diagnosed with FR had greater DOF than yearling cattle ($P < 0.01$); however, all cattle types diagnosed with FR ranged in weight between 469 and 497 kg at the time of treatment (Table 4). Cattle with INJ were diagnosed relatively early (DOF < 62 d), and throughout the year but no significant differences were found comparing the genders or ages of calves ($P > 0.05$). Calves with LNVS were in the lightest weight category at treatment (263 to 286 kg), and diagnosed early in the feeding cycle (25 to 26 d; $P < 0.01$ for both genders).

Animal Type and Gender Associated with Lameness Diagnosis

Tables 5 through 8 present the model outcomes of the associations of the four lameness diagnoses with animal type and gender as explanatory variables. In short, winter- and fall-placed calves were more likely to be diagnosed with FR compared to yearlings (OR: 1.19, 95% CI: 1.10–1.30 and OR: 1.46, 95% CI: 1.38–1.55, respectively). Winter-placed heifers were at low risk of developing FR (OR: 0.694, 95% CI: 0.60–0.79) compared to yearling heifers (Table 5), whereas fall-placed steers were more likely to be diagnosed with FR (OR: 1.43, 95% CI: 1.33–1.54) and winter-placed steers less likely (OR: 0.83, 95% CI: 0.74–0.93) compared to yearlings.

Gender and animal-type effects for INJ are summarized in Table 6. Fall-placed calves were more likely to have injuries compared to yearlings. Winter-placed heifers had 2.54 higher odds of being diagnosed with injuries compared to yearling heifers (OR: 2.54, 95% CI: 1.09–5.89). Also, fall-placed steers had 2.27 (95% CI: 1.50–3.42) times greater odds of developing an INJ compared to yearling steers.

Fall-placed calves were more likely to be diagnosed with JI compared to yearlings (OR: 3.64, 95% CI: 3.12–4.24), but steers had lower odds than heifers (OR: 0.69, 95% CI: 0.55–0.87). Both winter- and fall-placed heifers were more likely to be diagnosed with a JI compared to yearling heifers. This was the same for fall- and winter-placed steers compared to yearling steers (Table 7). Fall-placed calves had significantly higher odds of LNVS compared to yearlings (OR: 9.10, 95% CI: 6.26–13.2; Table 8), with steers having 2.46 higher odds compared to heifers. Fall-placed steer calves had the highest odds of being diagnosed with LNVS (OR: 2.82, 95% CI: 2.09–3.80) compared to yearling steers.

Table 5. Animal type and gender associated with foot rot diagnosis

Variable	Coefficient	Odds ratio	95% CI	*P*-value
Intercept	−5.21			<0.0001
Animal type				
Yearling	Referent			
Winter-calves	0.181	1.19	1.10–1.30	<0.0001
Fall-calves	0.383	1.46	1.38–1.55	<0.0001
Gender				
Heifer	Referent			
Steer	−0.063	0.938	0.873–1.00	0.082
Animal type * heifer				
Yearling * heifer	Referent			
Winter * heifer	0.364	0.694	0.603–0.799	<0.0001
Fall * heifer	0.020	0.979	0.895–1.07	0.660
Animal type * steer				
Yearling * steer	Referent			
Winter * steer	−0.182	0.833	0.743–0.933	0.002
Fall * steer	0.363	1.43	1.33–1.54	<0.0001
Random effect	Estimate	SEM	95% CI	
Feedlot	2.00	0.313	1.47–2.72	

Table 6. Animal type and gender associated with injuries

Variable	Coefficient	Odds ratio	95% CI	*P*-value
Intercept	−8.00			<0.0001
Animal type				
Yearling	Referent			
Winter-calves	−0.634	0.530	0.284–0.986	0.045
Fall-calves	0.816	2.26	1.70–2.99	<0.0001
Gender				
Heifer	Referent			
Steer	−0.388	0.677	0.445–1.03	0.069
Animal type * heifer				
Yearling * heifer	Referent			
Winter * heifer	0.932	2.54	1.09–5.89	0.030
Fall * heifer	0.004	1.00	0.619–1.62	0.985
Animal type * steer				
Yearling * steer	Referent			
Winter * steer	0.297	1.34	0.757–2.39	0.311
Fall * steer	0.821	2.27	1.50–3.42	<0.0001
Random effect	Estimate	SEM	95% CI	
Feedlot	1.81	0.626	0.922–3.56	

Cases of Lameness Associated with Occurrence of BRD Diagnosis

Of the 2,057 cattle with both lameness and BRD, a total of N = 1,480 were first diagnosed with BRD and then with lameness. There were 572 cattle initially diagnosed as lame that had a subsequent diagnosis of BRD. The interval between the initial episode of BRD and subsequent lameness was 21.5 ± 15.5 d (range, 1 to 60), whereas the interval between an initial case of lameness and a subsequent BRD diagnosis was 17.3 ± 14.0 d (range, 1 to 60). Intervals between an initial case of lameness and a case of BRD thereafter, and vice versa, were different ($P < 0.05$). After an episode of FR, cattle were less likely to be diagnosed with BRD (OR: 0.23, 95% CI: 0.20–0.28) (Table 9). However, there was greater odds of developing BRD after an INJ diagnosis (OR: 3.17, 95% CI: 2.36–4.25). Similarly, BRD was more likely after a JI diagnosis (OR: 3.37, 95% CI: 2.83–4.01). Cattle initially diagnosed with LNVS had a 3.66 greater odds (95% CI: 2.9–4.4) of being

Table 7. Animal type and gender associated with joint infections

Variable	Coefficient	Odds ratio	95% CI	*P*-value
Intercept	−6.70			<0.0001
Animal type				
Yearling	Referent			
Winter-calves	−0.212	0.808	0.611–1.06	0.136
Fall-calves	1.29	3.64	3.12–4.24	<0.0001
Gender				
Heifer	Referent			
Steer	−0.374	0.687	0.545–0.867	0.002
Animal type * heifer				
Yearling * heifer	Referent			
Winter * heifer	0.863	2.37	1.60–3.50	<0.0001
Fall * heifer	0.251	1.28	1.00–1.64	0.046
Animal type * steer				
Yearling * steer	Referent			
Winter * steer	0.650	1.91	1.45–2.52	<0.0001
Fall * steer	1.54	4.68	3.80–5.75	<0.0001
Random effect	Estimate	SEM	95% CI	
Feedlot	1.69	0.540	0.906–3.16	

Table 8. Animal type and gender associated with lame with no visible swelling

Variable	Coefficient	Odds ratio	95% CI	*P*-value
Intercept	−8.96			<0.0001
Animal type				
Yearling	Referent			
Winter-calves	0.244	1.27	0.673–2.41	0.453
Fall-calves	2.20	9.10	6.26–13.2	<0.0001
Gender				
Heifer	Referent			
Steer	0.900	2.46	1.57–3.84	<0.0001
Animal type * heifer				
Yearling * heifer	Referent			
Winter * heifer	−0.360	0.697	0.304–1.59	0.171
Fall * heifer	−1.17	0.309	0.194–0.494	<0.0001
Animal type * steer				
Yearling * steer	Referent			
Winter * steer	−0.115	0.890	0.523–1.51	0.669
Fall * steer	1.03	2.82	2.09–3.80	<0.0001
Random effect	Estimate	SEM	95% CI	
Feedlot	4.93	1.92	2.29–10.6	

diagnosed with BRD (Table 9). Conversely, if cattle were initially diagnosed with BRD, they had subsequently lower odds of being diagnosed as lame.

DISCUSSION

The Importance of Lameness in Feedlot Animals

The present study used a feedlot treatment records database consisting of information from 28 feedlots within Alberta over a 10-yr period to study lameness prevalence and associations with animal type and gender. The estimated treatment prevalence for lameness in this study was 32%. This is significantly greater compared to a lameness prevalence of 16% reported in a previous retrospective study of five large western United States feedlots with ~1.84 million animal health records (Griffin et al., 1993). The difference in lameness prevalence between studies may be due to increased awareness of producers and the cattle industry as the studies are executed 25 yr apart, as well as increasing welfare concerns regarding lameness, or an absolute

Table 9. Results from four logistic regression models that estimated odds of being diagnosed with BRD after being diagnosed as lame

Variable	Coefficient	Odds ratio	95% CI	*P*-value
Intercept	3.93			<0.0001
Foot rot		0.23	0.197– 0.275	<0.0001
Intercept	0.031			<0.0001
Injury		3.17	2.36–4.25	<0.0001
Intercept	0.063			<0.0001
Lame—no swelling		3.66	2.95–4.55	<0.0001
Intercept	0.171			<0.0001
Joint infection		3.37	2.83–4.01	<0.0001

increase in lameness prevalence. Terrell et al. (2017) reported lameness scores in six commercial beef feedlots in the United States and found a lameness incidence rate of 1.04 cases/100 animal-years. A Canadian study by Hendrick and Abeysekara (2014) found incidence risks in feedlot cattle of 4.2%, 0.9%, and 5.1% for FR, JI, and INJ/laminitis, respectively. These variations and the high occurrence of lameness highlight the need for epidemiology focused lameness research and improved lameness diagnostics.

Common Lameness Diagnoses

In a recent survey of 147 feedlot veterinarians, nutritionists, and managers, FR (42.2% of participants), INJ (35.4% of participants), and toe ulcer or abscess (10% of participants) were perceived as the most common cause of lameness in feedlot cattle (Terrell et al., 2014). In the retrospective study conducted by Griffin et al. (1993) consisting of >1 million records, approximately 70% of all lameness cases were attributed to diseases of the feet such as FR, whereas 15% were attributed to musculoskeletal injuries, septic joints attributed 12%, and lastly 3% was due to inflamed injection sites. Van Metre et al. (2005) also concluded that the majority (88% to 92%) of lameness in beef cattle involved the foot. In a retrospective study in the United States, medical records were reviewed for causes of lameness. They also identified that most lameness cases were located in the foot (85%) and 70% in the hind, with screw claw, vertical fissure, and interdigital fibroma as most important causes for lameness (Newcomer and Chamorro, 2016).

Moreover, in the present study, FR, a disorder of the foot, was the most common lameness diagnosis (74.5%), followed by JI, LNVS, and INJ at 16.1%, 6.1%, and 3.1%, respectively. It is likely that differences in perception and recorded diagnoses can be due to training level associated with lameness detection, and changes over the 10-yr period of the study. The latter is especially true for toe tip necrosis (TTN) and digital dermatitis; two emerging causes of lameness in Canadian feedlots. Furthermore, differences among countries, including management and environmental conditions, could have contributed to the differences in lameness prevalence observed between the current study and those reported in literature.

Risk Factors for Common Lameness Diagnoses

Exposure to excessive m, frozen ground, or even extremely dry conditions may compromise the skin barrier and can therefore be identified as risk factors for FR (Tibbetts et al., 2006). This likely explains the higher treatment rates for FR in spring and summer. With *Fusobacterium necrophorum* present in the environment, infection can occur, resulting in FR (Stokka et al., 2001). Therefore, cleaning feedlot pens frequently, ensuring good footing and removing sharp objects that could compromise the skin barrier, should reduce occurrence of FR.

With a 10-yr study, it is likely that misclassification has occurred. For example, some cattle diagnosed with FR actually could have been affected by digital dermatitis, which has presented as an emerging disease in the feedlots (Orsel et al., 2017). Digital dermatitis is a polymicrobial disease, associated with a species of anaerobic bacteria *Treponeme* spp. that can spread in contaminated soil or mud (Orsel et al., 2017). Lameness with no visible swelling would include the currently more common disease TTN (Gyan et al., 2015), which is more common earlier in the feeding period (i.e., fall), and although not misclassified, TTN was not given as a separate from lameness with no swelling in our study. Cattle with excitable temperaments may have increased chances of INJ as well as TTN ((Miskimins, 1994; Jelinski et al., 2016); therefore, consistent quiet handing on arrival throughout the feeding period could lower INJ risks, whereas aggressive handling may increase susceptibility to lameness. It is hypothesized that TTN is associated with handling calves on abrasive surfaces such as slatted concrete on arrival (Jelinski et al., 2016). Our health records, however, did not classify animals with TTN.

Risk Factors for Lameness Related to Age and Gender

Cattle type was a risk factor associated with a diagnosis of lameness. For all four lameness diagnoses, fall-placed calves were at higher risk of being diagnosed, compared to yearlings. In a recent study in 2014, fall-placed calves were also reported to be more susceptible to lameness than yearlings (16.1% vs. 11.6%, respectively; Hendrick and Abeysekara, 2014). In contrast to unconditioned fall-placed calves, winter-placed calves and yearling cattle are usually backgrounded before arrival at a feedlot and are more used to handling, including being in a chute. Also, they are likely accustomed to a feed bunk, are heavier, better preconditioned, and overall, less likely to be affected by lameness (Taylor et al., 2010). Fall-placed calves had greater odds of being diagnosed as LNVS, which could include cases of TTN, most commonly diagnosed earlier in the feeding period (Jelinski et al., 2016).

Fall-placed calves were also at high risk of injury. This may be due to the increased number of handling events they were exposed to (compared to yearlings) including processing, revaccination, and implanting, which increases the chance of being injured. Low-stress cattle handling is recommended to reduce the risk of injuries during handling (Noffsinger et al., 2015).

Steers had greater odds of being diagnosed with LNVS compared to heifers, and lower odds for JI. Overall, we found 4.4% vs. 4.7% of the steers and heifers affected, respectively. However, Hendrick and Abeysekara (2014) reported lameness was more common in steers than heifers (14.7% vs. 12.2%, $P < 0.05$). The analysis of the combined effect of gender and age showed that fall-placed steers were at higher risk compared to yearling steers and the winter heifers had a greater odds of being diagnosed with FR, INJ, and JI compared to yearling heifers. Differences in ADG and higher animal weight at slaughter may contribute to differences in lameness between steers and heifers. In beef bulls, greater initial body weight increased the risk of lameness (Wells et al., 1993). Similarly, clinical lameness in lactating dairy cows was found to increase 1.9 times for every 100 kg increase in body weight (Wells et al., 1993). Thus, heavier cattle may be more likely than light cattle to become lame, potentially due to increased weight bearing or other weight-related risks.

Association between Lameness and BRD Diagnosis

Bovine respiratory disease is the main cause of sickness in feedlot cattle associated with changes in behavior, reduced BCS, and immune function (White et al., 2012). In the present study, there were greater odds of BRD occurring after a diagnosis of lameness. Therefore, we inferred that changes in behavior (due to lameness) may have implications for development of BRD, as animals may separate themselves from the group and occupy less favorable parts of the pen. However, it could also be due to a direct association between BRD and lameness, as *Mycoplasma bovis* infection causes both lung and JI (Haines et al., 2001) with clinical signs of arthritis appear 1 or 2 wk after lung invasion of *M. bovis* causing signs of BRD (Caswell et al., 2010). However, if BRD occurred initially and lameness was a secondary diagnosis, there was no reduction in the odds for all four lameness diagnoses, suggesting that changes in behavior and potential immunosuppression due to BRD were less likely causing an increased risk of lameness. Potentially, lame cattle could have suppressed immunity, increasing their susceptibility to infections from commingling with other cattle shedding bacteria (Stokka et al., 2001). This potential immuno-suppression aligns with our findings that cattle diagnosed with INJ, JI or were LNVS, were approximately three times more likely to develop BRD.

Limitations of the Study

Due to the nature of this study, there were limitations and potential biases. Limitations included data quality, as numerous personnel at 28 feedlots made diagnoses and entered data into the chute-side health records system. Due to the duration of the study and its retrospective nature, no repeatability or interobserver comparisons could be done. Consequently, identification and recording of some diagnoses may have been incorrect or inconsistent. The Medlogic program used for the study was used infrequently in the first 4 yr of the study for lameness diagnoses recording, and was updated to include a new lameness category (LNVS) in 2009. Previously, cattle in the LNVS category were likely classified as INJ or in the OTHER. Consequently, the LNVS category did not have data collected throughout the study and as such, its true prevalence was likely underestimated. Due to limited lameness categories, diagnoses such as digital dermatitis were likely classified as FR and TTN as LNVS. The data set used in this study represented southern Alberta feedlots and not all of Alberta or Canada; however, 70% of the Canadian cattle are fed in Alberta and therefore likely representative to the majority of Canadian feedlot cattle under similar management.

This is one of few studies documenting the prevalence and risk factors associated with lameness in Canadian feedlot cattle. With the higher odds for fall-placed calves, especially steers, to be affected by lameness, it allows feedlot managers to reallocate resources to diagnose and treatment lameness. In addition, the association between lameness and BRD indicates that prompt intervention could avoid the chronicity of multiple disease diagnoses occurring.

SUPPLEMENTARY DATA

Supplementary data are available at *Translational Animal Science* online.

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Conflict of interest statement. None declared.

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