An epidemiological investigation to determine the prevalence and clinical manifestations of slow-moving finished cattle presented to slaughter facilities[1]

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ABSTRACT: Cattle mobility is routinely measured at commercial slaughter facilities. However, the clinical signs and underlying causes of impaired mobility of cattle presented to slaughter facilities are poorly defined. As such, the objectives of this study were 1) to determine the prevalence of impaired mobility in finished cattle using a 4-point mobility scoring system and 2) to observe clinical signs in order to provide clinical diagnoses for this subset of affected cattle. Finished beef cattle (n = 65,600) were observed by a veterinarian during the morning shift from six commercial abattoirs dispersed across the United States; the veterinarian assigned mobility scores (**MS**) to all animals using a 1–4 scale from the North American Meat Institute's Mobility Scoring System, with 1 = normal mobility and 4 = extremely limited mobility. Prevalence of MS 1, 2, 3, and 4 was 97.02%, 2.69%, 0.27%, and 0.01%, respectively. Animals with an abnormal MS (MS > 1) were then assigned to one of five clinical observation categories: 1) lameness, 2) poor conformation, 3) laminitis, 4) Fatigued Cattle Syndrome (**FCS**), and 5) general stiffness. Of all cattle observed, 0.23% were categorized as lame, 0.20% as having poor conformation, 0.72% as displaying signs of laminitis, 0.14% as FCS, and 1.68% as showing general stiffness. The prevalence of lameness and general stiffness was greater in steers than heifers, whereas the prevalence of laminitis was the opposite ($P < 0.05$). FCS prevalence was higher in dairy cattle than in beef cattle (0.31% vs. 0.22%, respectively; $P \leq 0.05$). These data indicate the prevalence of cattle displaying abnormal mobility at slaughter is low and causes of abnormal mobility are multifactorial.

Key words: animal welfare, cattle mobility, Fatigued Cattle Syndrome, lameness

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INTRODUCTION

The mobility of finished cattle presented for slaughter gained attention after an adverse animal welfare event was reported in 2013, heightening awareness of and concern about severe fatigue and its effects, a condition now defined as "Fatigued

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Cattle Syndrome" (Vance, 2013; Thomson et al., 2015). A similar condition has been described in swine where a portion of hogs exposed to stress at the time of transport display decreased mobility, and in extreme cases, become nonambulatory as the result of metabolic acidosis and muscle fatigue (Ritter et al., 2009). Reports of Fatigued Cattle Syndrome (**FCS**) typically occur in the hot summer months and manifest with clinical signs such as tachypnea, muscle tremors, a stiff gait with shortened strides, reluctance to move, and in severe cases, sloughing of the hoof wall (Thomson et al., 2015; Frese et al., 2016). Previous reports involving cattle diagnosed with FCS describe radical elevations in certain hematological variables such as lactate, creatine kinase (**CK**), and aspartate aminotransferase (**AST**) when compared with normal reference ranges (Thomson et al., 2015).

In 2015, the North American Meat Institute (**NAMI**) adopted a 4-point mobility scoring system to complement other traditional scoring systems designed to assess the mobility of finished cattle at commercial slaughter facilities (NAMI, 2015; Edwards-Callaway et al., 2017) While mobility scoring is now common, efforts to define the etiologies underlining finished cattle with abnormal mobility at slaughter have not been made. It is unlikely that all cattle with abnormal mobility scores (**MS**) are necessarily afflicted with FCS. Rather, some cattle may experience pain due to acute or chronic lameness due to laminitis or other causes, which can be amplified during the transport process (Stokka et al., 2001). Therefore, the objectives of this observational study were to determine the prevalence of cattle with abnormal mobility using the 4-point mobility scoring system and to determine what clinical signs and/or pathology may contribute to abnormal mobility in finished cattle presented to six commercial slaughter facilities across the United States.

MATERIALS AND METHODS

All procedures were approved by the Institutional Animal Care and Use Committee of Kansas State University (IACUC # 3708).

Slaughter facilities were selected on the basis of 1) geographical location and 2) where historical data on cattle mobility were available. The six facilities selected were in different locations across the United States, and their operations reflect the current population of finished cattle slaughtered in the United States, with each facility slaughtering over 1,500 cattle in a single 8-h shift. Observations were made during the months of April through August in 2016, and each facility was visited on five different weekdays throughout the summer so that scoring could be completed on each day of the business week (Monday through Friday). This approach was used to eliminate potential confounding effects of observing cattle on the same day over multiple weeks, as type and background of cattle may vary within a week based on slaughter facility procurement strategies.

Weather measurements were obtained from the nearest local weather station at the beginning and end of each shift and included ambient temperature (°C), percent humidity, and wind speed (mph). The following information was recorded for each lot of cattle observed: feedlot of origin (to determine distance transported), slaughter facility lot number, number of cattle in the lot, cattle type (beef or dairy), sex (categorized as steer, heifer, or mixed), and distance transported. Flooring type of each facility was also recorded but not included in the analysis, as only one facility used different flooring. Temperature and humidity recorded at the end of each shift were used to determine the day's temperature–humidity index (**THI**), using the equation from Mader et al. (2010) where:

THI = (0.8 × ambient temperature in °C) + [(% relative humidity/100) × (ambient temperature in °C – 14.4)] + 46.4

Categories for ambient temperature, THI, and distance traveled were selected based on common numeric categories, such as every 5 degrees, and every 100 miles. Time of observation was also recorded. Average lairage time for each lot was recorded and expressed as Lairage Time = time of observation−average of the times all trucks carrying the lot passed over the slaughter facility scale. This measurement therefore included the time cattle spent on the trucks waiting to be unloaded, time spent on the unloading dock, and time spent in lairage pens.

Regardless of slaughter facility, cattle were observed between the hours of 0600 and 1600 (the entirety of shift 1) after being removed from lairage pens, on their way to the serpentine alley that led to the restrainer. Observation locations were not the same at each facility due to logistical considerations; however, all observations were made at the same point of the animals' drive from lairage pens to the restrainer. The observer was trained using training videos provided by the NAMI (NAMI, 2015). An MS was assigned to each of the 65,600 animals observed by the same trained veterinarian (T.L.L) using the scoring system adopted by the

NAMI (NAMI, 2015), where: 1 = Normal, walks easily with no apparent lameness or change in gait; 2 = Keeps up with normal cattle when the group is walking, exhibits one or more of the following: stiffness, shortened stride, or slight limp; 3 = Lags behind normal cattle when the group is walking, exhibits one or more of the following: obvious stiffness, difficulty taking steps, obvious limp, or discomfort; 4 = Extremely reluctant to move, even when encouraged by handlers. Whereas cattle with normal mobility (MS = 1) were not uniquely identified, any animal receiving an MS ≥ 2 was considered to have impaired mobility and observed further by the same veterinarian who categorized the observed clinical signs into one of the following five groups: 1) lameness/injury other than laminitis (lameness), 2) poor conformation, 3) laminitis, 4) FCS, or 5) general stiffness. Evidence of musculoskeletal injury or disease was noted so that cases of lameness attributable to ailments such as infectious pododermatitis, fractures of the extremities, or broken hoof walls were combined into the same lameness category (1). Cattle with abnormal elongation of hooves, concavity of the dorsal hoof margin, and flattening/broadening of the sole were categorized as affected by chronic laminitis or founder (Boosman et al., 1991, 2). Poor conformation was defined with the use of the University of Arkansas' Analysis of Beef Cattle Conformation and was characterized by abnormalities in shape or structure of legs and feet (Barham et al., 3). Of particular interest in the current study, the final two etiology categories described cattle without obvious disease or injury, which became reluctant to move or failed to keep up with their contemporaries, and had shortened strides, stiffened gait, and difficulty walking. Because acute signs of stress, including but not limited to increased respiration rates, vocalization, severe stiffness, and muscle tremors, have been described with cattle affected by FCS, the presence of these clinical signs was used to distinguish FCS (4) from general stiffness (5).

Data were entered and tabulated in a Microsoft Excel spreadsheet (Microsoft Excel® software, Microsoft, Spokane, WA). Means, SDs, frequency distributions, and minimum and maximum values for prevalence of MS and clinical diagnoses were calculated using spreadsheet formulas. Data were further analyzed using the PROC GLIMMIX procedure to perform univariable analyses in SAS v. 9.4 (SAS Inst. Inc., Cary, NC). Because this is an exploratory prevalence study and the primary objective was to determine the prevalence of and clinical signs associated with abnormal mobility, multivariable analyses were not performed; therefore, no interactions or specific random effects were included. The univariable analyses conducted were to identify specific risk factors that may warrant further investigation.

Each abnormal MS (i.e., MS 2, 3, and 4) and each clinical diagnosis category (lameness, poor conformation, laminitis, FCS, and general stiffness) were considered dependent variables. Sex, breed, high ambient temperature, afternoon THI, distance traveled, average lairage time, and time of observation were treated as independent variables. Comparisons of least square mean (**LSMEAN**) estimates of the independent variables were made between categories of each dependent variable using the LSMEANS procedure, with a Tukey–Kramer adjustment for multiple comparisons. The count of the observations per group was assumed to follow a Poisson distribution, and the natural logarithm of the cattle in the group was treated as the offset (denominator) variable. An overdispersion term was included in the model to account for within-group dependency of each outcome and to inflate variance associated with the model estimates. Statistical significance was determined at $P \leq 0.05$.

RESULTS

A total of 65,600 finished cattle were observed at six slaughter facilities over 30 individual observation days, with steers (n = 39,690) representing more of the sample population than heifers (n = 19,734) and animals comprising lots of mixed sexes (n = 6,176) representing less than 10% of the sample population. These data reflect the current industry population of slaughtered steers and heifers, in which steers represent approximately 55% of the population and heifers represent approximately 25% (USDA AMS, 2017). There were a greater number of beef breed cattle observed than cattle from dairy breeds (n = 58,124 vs. 7,476, respectively).

Across observation days, the minimum temperature ranged from 3.8 °C to 22.2 °C, while the maximum temperature ranged from 18.9 °C to 37.2°C. Distance traveled by cattle coming into the slaughter facilities ranged from 8 to 1,917 km. Average lairage time ranged from 30 min to over 12 h. In all but one facility, which had both grooved concrete and rebar, grooved concrete was the flooring surface in the lairage pens and alley ways.

Overall, cattle receiving an MS = 1 were most prevalent (97.02%; Table 1), cattle receiving an MS = 4 were least prevalent (0.01%), and cattle receiving MS 2 or 3 were intermediate (2.69% and

Table 1. Overall prevalence of MS 1, 2, 3, and 4 in 65,600 finished cattle observed across six commercial slaughter facilities

MS*	Count	Percent %
1	63,647	97.02
2	1,767	2.69
3	180	0.27
4	6	0.01

*MS was assigned to each animal observed using the scoring system adopted by the NAMI, where: 1 = Normal, walks easily with no apparent lameness or change in gait; 2 = Keeps up with normal cattle when the group is walking, exhibits one or more of the following: stiffness, shortened stride, or slight limp; 3 = Lags behind normal cattle when the group is walking, exhibits one or more of the following: obvious stiffness, difficulty taking steps, obvious limp, or discomfort; 4 = Extremely reluctant to move, even when encouraged by handlers.

0.27%, respectively; Table 1). The total count of MS in all cattle observed is summarized by sex and breed in Table 2. Overall prevalence of each clinical observation category and the proportion of each etiology within the cattle observed are presented in Table 3. Of the five clinical observation categories, general stiffness represented the greatest proportion of cattle with MS >1, with laminitis and lameness being the next most common. When considering each MS >1, general stiffness was the biggest contributor to prevalence of animals displaying MS = 2 (Table 3), whereas the greatest proportion of cattle receiving MS 3 and 4 displayed signs of FCS. Of all clinical signs observed in cattle displaying abnormal MS, shortened strides and stiffness were most commonly reported (Table 4).

Table 2. Total count of MS in 65,600 finished cattle summarized by sex and breed across six commercial slaughter facilities

	Beef			Dairy*		
MS†	Heifer	Mixed lot‡	Steer	Heifer	Mixed lot	Steer
1	18,862	5,485	32,069	354	513	6,364
2	476	154	924	7	10	196
3	33	12	104	2	2	27
4	0	0	5	0	0	1

*MS was assigned to each animal observed using the scoring system adopted by the NAMI, where: 1 = Normal, walks easily with no apparent lameness or change in gait; 2 = Keeps up with normal cattle when the group is walking, exhibits one or more of the following: stiffness, shortened stride, or slight limp; 3 = Lags behind normal cattle when the group is walking, exhibits one or more of the following: obvious stiffness, difficulty taking steps, obvious limp, or discomfort; 4 = Extremely reluctant to move, even when encouraged by handlers.

†"Dairy" refers to Holstein animals.

‡"Mixed lot" refers to animals which came in lots comprised of both heifers and steers.

Table 3. Percentage of cattle displaying abnormal MS (MS ≥ 2) categorized by clinical observation in 65,600 finished cattle across six commercial slaughter facilities

		MS*			
Clinical observation	Total count	2	3	4	Percent of total observations % (n = 65,600)
Lameness†	153	132	19	2	0.23
Poor conformation‡	130	121	9	0	0.20
Laminitis‖	471	423	47	1	0.72
FCS$	94	1	90	3	0.14
General stiffness¶	1,105	1,090	15	0	1.68

*MS was assigned to each animal observed using the scoring system adopted by the NAMI, where: 1 = Normal, walks easily with no apparent lameness or change in gait; 2 = Keeps up with normal cattle when the group is walking, exhibits one or more of the following: stiffness, shortened stride, or slight limp; 3 = Lags behind normal cattle when the group is walking, exhibits one or more of the following: obvious stiffness, difficulty taking steps, obvious limp, or discomfort; 4 = Extremely reluctant to move, even when encouraged by handlers.

†Lameness/injury (other than laminitis) was defined as obvious lameness on one or more limbs caused by broken toes or legs, or any shoulder or rear leg injuries.

‡Poor conformation was defined as abnormalities in shape or structure of legs and feet, which may affect cattle mobility.

‖Laminitis was defined as founder/laminitis including animals with abnormally long hooves, animals walking on their heels, presence of cracked hooves, concavity of the dorsal hoof margin, flattening/broadening of the sole, or possibly sloughed hoof walls.

$FCS was defined as animals displaying abnormal mobility, with clinical signs not due to injury or founder, including but not limited to nervous system abnormalities such as muscle tremors, increased respiratory rate, increased vocalization, obvious stiffness, and shortened strides.

¶General stiffness was recorded when animals presented with abnormal mobility not due to any obvious disease, injury, or syndrome. Stiff cattle displayed normal behavior with the exception of abnormal mobility or range of movement.

Table 4. Number of cattle (n = 65,600) displaying clinical signs within each clinical observation category across six commercial slaughter facilities

Clinical sign	Lameness* (n = 153)	Poor conformation† (n = 130)	Laminitis‖ (n = 471)	FCS$ (n = 94)	General stiffness¶ (n = 1,106)
Lame	151	0	0	0	2
Broken leg	1	0	0	0	0
Broken toe	3	0	2	0	0
Sloughed hoof	0	0	0	0	0
Long toes	2	2	466	7	5
Shortened strides	10	105	420	92	1,004
Walking on heels	0	1	59	0	0
Increased respiratory rate	1	0	1	41	13
Muscle tremors	3	1	1	82	9
Stiffness	4	41	41	91	1,042
Vocalization	0	0	0	0	0
Nonambulatory	0	0	0	1	0

Clinical signs were not mutually exclusive.

*Lameness/injury (other than laminitis) was defined as obvious lameness on one or more limbs caused by broken toes or legs, or any shoulder or rear leg injuries.

†Poor conformation was defined as abnormalities in shape or structure of legs and feet, which may affect cattle mobility.

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¶General stiffness was recorded when animals presented with abnormal mobility not due to any obvious disease, injury, or syndrome. Stiff cattle displayed normal behavior with the exception of abnormal mobility or range of movement.

Lots comprised of steers exhibited a higher prevalence of abnormal MS than lots comprised of heifers and animals from mixed lots (1.92% vs. 0.79% and 0.27%, respectively); however, no statistically significant differences were detected between animals of different sexes within each abnormal MS category ($P > 0.05$). There were no significant differences detected in the prevalence of abnormal MS between breeds ($P > 0.05$). All animals displaying MS = 4 were steers, with five being of beef breeds and one of dairy. Ambient temperature and THI were not observed to have an effect on the prevalence of abnormal mobility ($P > 0.05$).

There was no observed effect of distance transported on the prevalence of MS 2 or 4 (Figure 1A and B; $P > 0.05$). On the other hand, the prevalence of cattle receiving an MS of 3 was lower in lots shipped 0–161 km compared with 162–321 km and 322–483 km (Figure 1B; $P = 0.0114$ and 0.003, respectively), but no difference was observed in prevalence of MS = 3 in cattle that had traveled over 482 km ($P > 0.05$). Prevalence of MS 2 and 3 increased as average lairage time increased up to 8 h ($P < 0.01$, $P < 0.01$, respectively), then became more variable up to and over 12 h (Figure 2B). There were no differences detected in MS = 4 at different average lairage times ($P < 0.05$). Additionally, there were no differences detected in prevalence of cattle receiving abnormal MS across different times of the shift when cattle were observed ($P > 0.05$).

Lameness was more prevalent in lots comprised of steers than lots comprised of heifers ($P < 0.05$), whereas no differences in the prevalence of lameness were detected in lots of mixed sex when compared with lots of heifers or steers ($P > 0.05$, respectively). Laminitis was more prevalent in heifers than in steers ($P < 0.05$), but the prevalence of laminitis in mixed-sex lots was similar to that in lots of heifers or steers ($P < 0.05$). A greater proportion of steers displayed general stiffness compared with heifers ($P < 0.05$), but no difference was detected when mixed lots were compared with lots of steers or heifers ($P > 0.05$). There were no observed differences in the prevalence of poor conformation or FCS across lots of steers, heifers, and mixed sex ($P > 0.05$). Prevalence of FCS was greater in dairy breeds compared with beef breeds (0.28% vs. 0.13%, respectively; $P < 0.05$; Table 5). However, no effects of breed type on any of the other four clinical observation categories were observed. There were no differences detected for the prevalence of laminitis, FCS, or general stiffness across different ambient temperatures ($P > 0.05$). Regarding THI, the prevalence of lameness was greater at THIs between 50 and 57.9 and 62 and 65.9 compared with THIs of 66 to 69.9 ($P < 0.05$). No differences

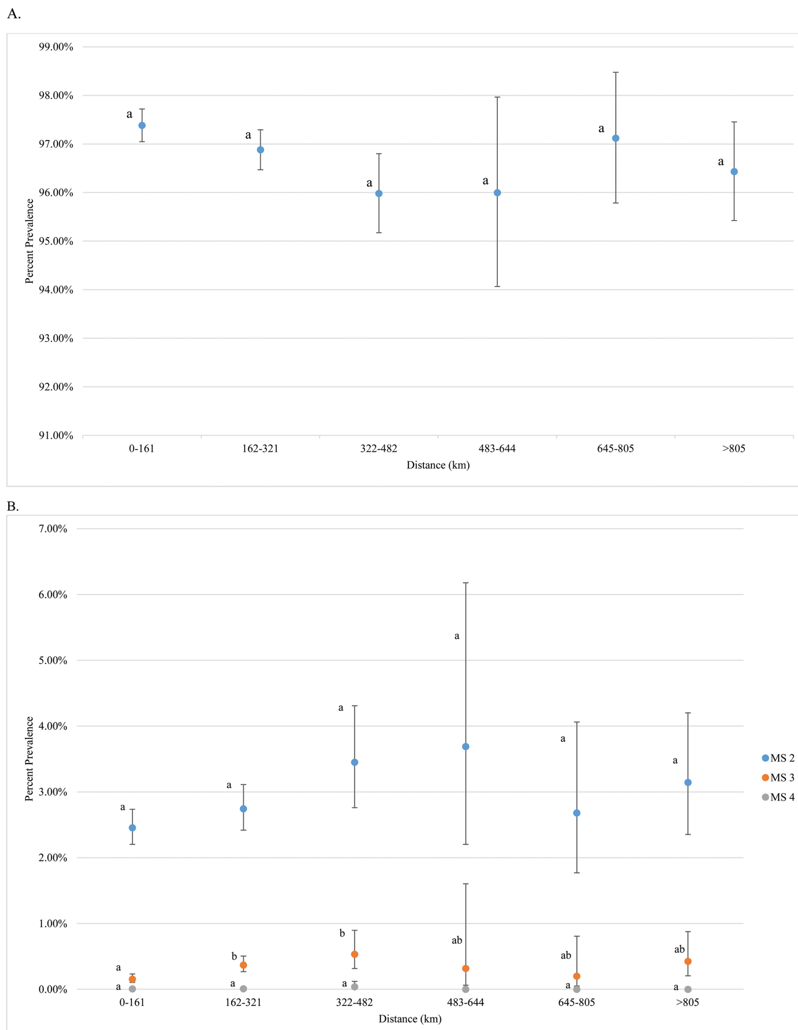

Figure 1. Comparisons of point estimates for normal (A) and abnormal (B) MS prevalence categorized by distance traveled in 65,600 finished cattle at six commercial slaughter facilities. Variation is expressed as 95% CIs, and estimates for each MS without common superscripts differ ($P \leq 0.05$).

between the prevalence of laminitis were detected across different levels of THI ($P > 0.05$).

No differences were detected in prevalence of lameness and poor conformation relative to distance transported ($P > 0.05$; Table 6); however, distance transported impacted the proportion of cattle diagnosed with laminitis, FCS, and general stiffness ($P \leq 0.05$). Laminitis was more common in cattle transported 484–643 km compared with those traveling 163–322 km ($P < 0.01$), but no differences in prevalence of laminitis were detected when these animals were compared with animals traveling any other distance ($P > 0.05$). The prevalence of FCS was lower in cattle transported 0–162 km vs. 323–482 km ($P < 0.01$), but no differences in FCS prevalence were observed between any other two distances ($P > 0.05$). General stiffness increased with distance up to 482 km ($P < 0.01$), after which no differences were observed. No differences were detected in the prevalence of lameness and poor conformation with regards to lairage time ($P > 0.05$; Table 7). Prevalence of laminitis was greater in animals experiencing a lairage time of 8–10 h and >12 h compared with those spending 0–2 h in lairage ($P < 0.01$), but no other differences were detected between any other two distance categories. Animals experiencing lairage times of 0–2 h displayed a lower prevalence of FCS than those in lairage for 4 h ($P < 0.01$), but prevalence of FCS did not appear to differ when these groups were compared with other lairage times. Prevalence of general stiffness was greatest at 4–6 h lairage ($P < 0.01$). Animals experiencing lairage times >10 h displayed greater prevalence of general stiffness than those in lairage for <4 h ($P < 0.05$). There were no differences detected in the prevalence of laminitis, FCS, or general stiffness when compared across different times of observation ($P < 0.05$).

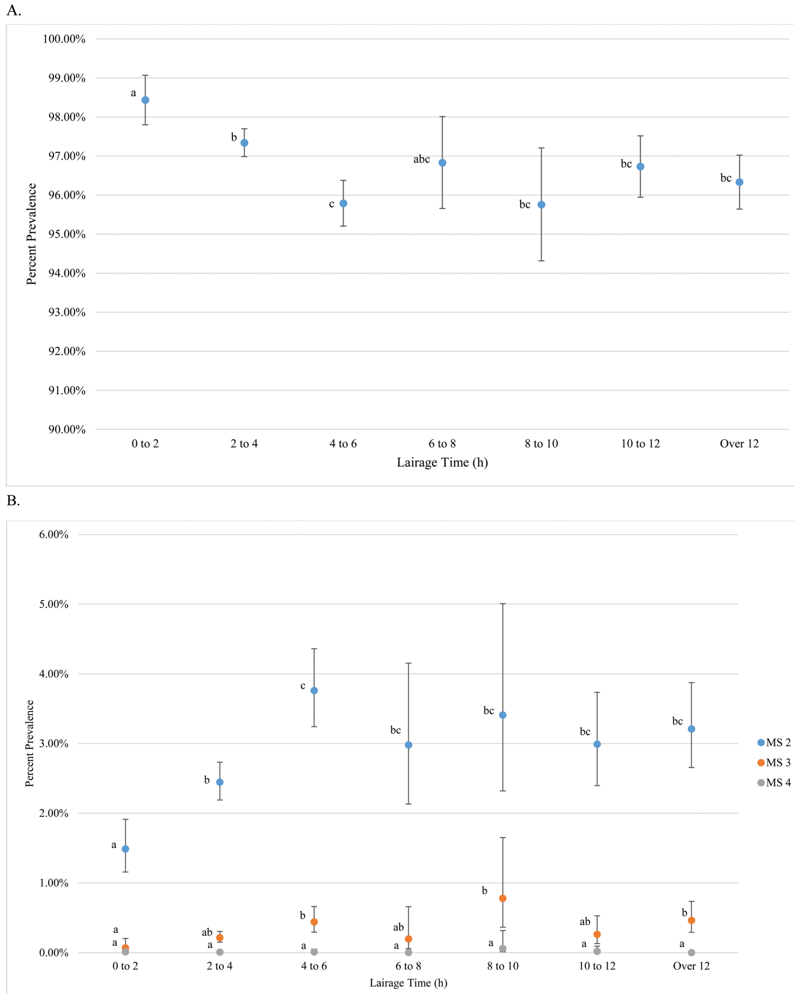

Figure 2. Comparison of point estimates for normal (A) and abnormal (B) MS prevalence categorized by average lairage time (h) in 65,600 finished cattle across six commercial slaughter facilities. Lairage time is defined as: Lairage Time = time of observation−average time the trucks carrying the lot passed over the slaughter facility scale. Variation is expressed as 95% CIs and estimates without common superscripts differ ($P \leq 0.05$).

DISCUSSION

This study is the first to describe the prevalence and clinical manifestations of impaired mobility in finished cattle presented to slaughter facilities in the United States. While the prevalence of cattle receiving an abnormal MS was relatively small (2.98%) and the prevalence of abnormal scores decreased with increasing severity, the subset of animals with impaired mobility present an animal welfare concern and warrant further discussion. This study helps identify potential risk factors contributing to abnormal mobility and provides information upon which future research studies can be designed.

While some authors suggest that increased ambient temperatures or seasonal changes cause an increase in abnormal cattle mobility at slaughter facilities (Gonzalez et al., 2012a; Loneragan et al., 2014), there was no effect of temperature or THI on the proportion of abnormal MS assigned in this study. However, all observations in the current study were made during the first slaughter shift, which typically occurs from 0600 to 1400 or 1500 h; therefore, cattle were not observed in the hottest hours of the day. Month of slaughter has been associated with increased mortality in finished cattle at the feedyard (Loneragan et al., 2014), but the contribution of abnormal mobility to such mortality has not been explored. In addition, because observations were made only in the late spring and summer months in this study, seasonal effects on the prevalence of abnormal MS could not be assessed.

Mader et al. (2010) suggested incorporating solar radiation and wind speed into THI calculations; however, such information was used in assessments of environmental stress in feedyards, not in slaughter facilities. Although solar radiation likely contributes to the heat load experienced by cattle temporarily held in slaughter facility lairage pens, wind may not be a major contributing factor in the ability of animals to cool themselves in such an environment because the lairage pens at slaughter facilities are relatively small with stocking densities

Table 5. Comparison of point estimates clinical diagnosis prevalence categorized by breed in 65,600 finished cattle across six commercial slaughter facilities

	Lameness*				Poor conformation[†]				Laminitis[‖]				FCS[§]				General stiffness[¶]			
Breed	Estimate	Lower CL**	Upper CL	*P* value	Estimate	Lower CL	Upper CL	*P* value	Estimate	Lower CL	Upper CL	*P* value	Estimate	Lower CL	Upper CL	*P* value	Estimate	Lower CL	Upper CL	*P* value
Beef	0.22%[a]	0.18%	0.28%	0.269	0.19%[a]	0.15%	0.25%	0.505	0.73%[a]	0.62%	0.85%	0.614	0.13%[a]	0.09%	0.17%	0.02	1.67%[a]	1.50%	1.87%	0.663
Dairy[††]	0.31%[a]	0.18%	0.52%		0.24%[a]	0.13%	0.44%		0.64%[a]	0.40%	1.02%		0.28%[b]	0.15%	0.51%		1.79%[a]	1.33%	2.41%	

Estimates of the prevalence of each clinical observation category without common superscripts differ ($P \leq 0.05$).

*Lameness/injury (other than laminitis) was defined as obvious lameness on one or more limbs caused by broken toes or legs, or any shoulder or rear leg injuries.

[†]Poor conformation was defined as abnormalities in shape or structure of legs and feet, which may affect cattle mobility.

[‖]Laminitis was defined as founder/laminitis including animals with abnormally long hooves, animals walking on their heels, presence of cracked hooves concavity of the dorsal hoof margin, flattening/broadening of the sole, or possibly sloughed hoof walls.

[§]FCS was defined as animals displaying abnormal mobility, with clinical signs not due to injury or founder, including but not limited to nervous system abnormalities such as muscle tremors, increased respiratory rate, increased vocalization, obvious stiffness, and shortened strides.

[¶]General stiffness was recorded when animals presented with abnormal mobility not due to any obvious disease, injury, or syndrome. Stiff cattle displayed normal behavior with the exception of abnormal mobility or range of movement.

**Confidence limit.

[††]"Dairy" refers to Holstein animals.

much greater than feedyard pens, likely eliminating most of the positive impact wind may have on the cooling abilities of cattle. Shade has been shown to decrease heat stress in cattle in feedyards, but the use of shade in slaughter facility lairage pens has not been evaluated (Boyd et al., 2015). Shade structures in lairage pens may in fact be detrimental to the animals' ability to dissipate heat, as shade structures may contribute to a further decrease in air flow throughout slaughter facility pens, but exploratory research into this hypothesis is needed.

The prevalence of cattle receiving an MS = 3 increased when distance transported to the slaughter facility increased up to approximately 480 km (Figure 2B). In swine, losses due to deceased or nonambulatory pigs increase as distance moved during loading and distance traveled increase (Ritter et al., 2007; Fitzgerald et al., 2009). Data collected in this study indicate prevalence of abnormal mobility increases to a certain distance traveled and/or lairage time, then stays the same or decreases. Gonzalez et al. (2012b) indicated that distance should be considered along with ambient temperature to mitigate the stress associated with transport; however, temperature was not recorded during transport in the current study.

In the current study, further distances transported and longer lairage times were associated with increased prevalence of FCS and general stiffness to a point (400 km distance, 8 h lairage), after which prevalence of each diagnosis decreased or stabilized. A substantial amount of research exists on the effects of distance traveled on stress and bruising in cattle, but such research does not include the assessment of cattle mobility or the presence of any abnormalities other than biomarkers of stress, including blood cortisol, lactate, catecholamines, CK, and others (Mitchell, 1988; Jarvis et al., 1995; Hoffman et al., 1998; Nanni Costa et al., 2003). In two separate studies, Frese et al. (2016) and Hagenmaier et al. (2017) reported that aggressive handling can increase stress markers such as lactate and CK in cattle and can have detrimental effects on mobility. Such associations between blood biomarkers and abnormal mobility are explored further in Lee et al. (unpublished data).

High or inconsistent feed intake could contribute to differences in the prevalence of laminitis. Research shows that Charolais-cross cattle fed a high-concentrate diet for 142 d had a net sole horn growth of 2.5 times greater than that of cattle fed a high-concentrate diet for 30 fewer days (Greenough et al., 1990). However, in the current

Table 6. Comparison of point estimates clinical diagnosis prevalence categorized by distance traveled in 65,600 finished cattle across six commercial slaughter facilities

	Lameness*				Poor conformation†				Laminitis‖				FCS$				General stiffness¶			
Distance (km)	Estimate	Lower CL**	Upper CL	*P* value	Estimate	Lower CL	Upper CL	*P* value	Estimate	Lower CL	Upper CL	*P* value	Estimate	Lower CL	Upper CL	*P* value	Estimate	Lower CL	Upper CL	*P* value
0–161	0.25%^{a}	0.19%	0.33%	0.798	0.20%^{a}	0.14%	0.28%	0.436	0.80%^{ab}	0.66%	0.97%	0.045	0.07%^{a}	0.04%	0.13%	0.008	1.29%^{a}	1.10%	1.52%	0.0002
162–321	0.22%^{a}	0.15%	0.32%		0.21%^{a}	0.14%	0.31%		0.54%^{a}	0.41%	0.73%		0.20%^{ab}	0.12%	0.31%		1.95%^{b}	1.65%	2.29%	
322–482	0.17%^{a}	0.07%	0.39%		0.13%^{a}	0.05%	0.36%		0.70%^{ab}	0.42%	1.16%		0.39%^{b}	0.20%	0.74%		2.64%^{b}	2.00%	3.49%	
483–644	0.21%^{a}	0.03%	1.27%		0.53%^{a}	0.16%	1.77%		1.90%^{b}	0.91%	3.95%		0.00%^{ab}	0.00%	.		1.37%^{ab}	0.54%	3.45%	
645–805	0.10%^{a}	0.02%	0.59%		0.30%^{a}	0.10%	0.90%		0.70%^{ab}	0.30%	1.60%		0.00%^{ab}	0.00%	.		1.79%^{ab}	1.03%	3.11%	
>805	0.31%^{a}	0.15%	0.67%		0.08%^{a}	0.02%	0.41%		0.74%^{ab}	0.40%	1.36%		0.23%^{ab}	0.08%	0.61%		2.21%^{ab}	1.52%	3.22%	

$^{a-c}$ Estimates of the prevalence of each clinical observation category without common superscripts differ ($P \leq 0.05$).

*Lameness/injury (other than laminitis) was defined as obvious lameness on one or more limbs caused by broken toes or legs, or any shoulder or rear leg injuries.

†Poor conformation was defined as abnormalities in shape or structure of legs and feet which may affect cattle mobility.

‖Laminitis was defined as founder/laminitis including animals with abnormally long hooves, animals walking on their heels, presence of cracked hooves, concavity of the dorsal hoof margin, flattening/broadening of the sole, or possibly sloughed hoof walls.

$FCS was defined as animals displaying abnormal mobility, with clinical signs not due to injury or founder, including but not limited to nervous system abnormalities such as muscle tremors, increased respiratory rate, increased vocalization, obvious stiffness, and shortened strides.

¶General stiffness was recorded when animals presented with abnormal mobility not due to any obvious disease, injury, or syndrome. Stiff cattle displayed normal behavior with the exception of abnormal mobility or range of movement.

**Confidence limit.

Table 7. Comparison of point estimates clinical observation prevalence categorized by average lairage time in 65,600 finished cattle across six commercial slaughter facilities

	Lameness*				Poor conformation†				Laminitis‖				FCS§				General stiffness¶			
Lairage time (h)	Estimate	Lower CL**	Upper CL	*P* value	Estimate	Lower CL	Upper CL	*P* value	Estimate	Lower CL	Upper CL	*P* value	Estimate	Lower CL	Upper CL	*P* value	Estimate	Lower CL	Upper CL	*P* value
0 to 2	0.10%[a]	0.04%	0.23%	0.313	0.10%[a]	0.04%	0.23%	0.03	0.45%[a]	0.27%	0.73%	0.056	0.03%[a]	0.01%	0.18%	0.016	0.88%[a]	0.62%	1.26%	<0.0001
2 to 4	0.23%[a]	0.17%	0.32%		0.16%[a]	0.11%	0.23%		0.74%[ab]	0.60%	0.92%		0.10%[ab]	0.06%	0.18%		1.43%[ab]	1.22%	1.68%	
4 to 6	0.21%[a]	0.12%	0.35%		0.26%[a]	0.17%	0.42%		0.62%[ab]	0.42%	0.91%		0.36%[b]	0.23%	0.58%		2.76%[c]	2.29%	3.34%	
6 to 8	0.35%[a]	0.15%	0.80%		0.43%[a]	0.21%	0.90%		0.82%[ab]	0.42%	1.62%		0.00%[ab]	0.00%	.		1.57%[abc]	0.95%	2.59%	
8 to 10	0.36%[a]	0.13%	0.98%		0.48%[a]	0.20%	1.14%		1.55%[b]	0.84%	2.86%		0.24%[ab]	0.05%	1.10%		1.61%[abc]	0.88%	2.97%	
10 to 12	0.24%[a]	0.13%	0.47%		0.17%[a]	0.08%	0.38%		0.66%[ab]	0.40%	1.10%		0.17%[ab]	0.07%	0.44%		2.01%[bc]	1.50%	2.70%	
Over 12	0.31%[a]	0.19%	0.52%		0.24%[a]	0.14%	0.44%		0.94%a[b]	0.64%	1.36%		0.15%[ab]	0.06%	0.36%		2.03%[bc]	1.56%	2.63%	

[a–c] Estimates of the prevalence of each clinical diagnosis without common superscripts differ ($P \leq 0.05$). Lairage time is defined as Lairage Time = time of observation−average time the trucks carrying the lot passed over the slaughter facility scale. Variation is expressed as 95% CIs and estimates without common superscripts differ ($P \leq 0.05$).

*Lameness/injury (other than laminitis) was defined as obvious lameness on one or more limbs caused by broken toes or legs, or any shoulder or rear leg injuries.

†Poor conformation was defined as abnormalities in shape or structure of legs and feet, which may affect cattle mobility.

‖Laminitis was defined as founder/laminitis including animals with abnormally long hooves, animals walking on their heels, presence of cracked hooves, concavity of the dorsal hoof margin, flattening/broadening of the sole, or possibly sloughed hoof walls.

§FCS was defined as animals displaying abnormal mobility, with clinical signs not due to injury or founder, including but not limited to nervous system abnormalities such as muscle tremors, increased respiratory rate, increased vocalization, obvious stiffness, and shortened strides.

¶General stiffness was recorded when animals presented with abnormal mobility not due to any obvious disease, injury, or syndrome. Stiff cattle displayed normal behavior with the exception of abnormal mobility or range of movement.

**Confidence limit.

study, no difference in the prevalence of laminitis in beef cattle is compared with that in dairy-breed cattle was observed, even though dairy-breed cattle typically require a greater number of days on feed than either steers or heifers of beef breeds (Mills et al., 1992).

With regard to the increased proportion of lameness and general stiffness observed in steers in the current study, it could be hypothesized that steers are more prone to fighting and are more temperamental than their female counterparts, although Voisinet et al. (1997) showed that heifers displayed greater temperament scores than steers. No data on temperament were collected in the current study, therefore increased lameness and general stiffness in steers cannot be attributed to temperament here. Differences in prevalence of FCS or poor conformation between sexes were not detected in this study.

Cattle of dairy breeds had a greater prevalence of FCS than beef breeds, possibly indicating they are more susceptible to the rigors of transport and lairage processes. In addition to typically being fed higher concentrate diets earlier in life than their beef counterparts, dairy cattle require more time to reach desirable end points for slaughter, resulting in longer days on feed (Mills et al., 1992). These factors could increase the risk of subclinical acidosis and unobservable subclinical laminitis, and it is possible that such pathology could be mistaken for fatigue (Greenough et al., 1990). Finally, it has been proposed that responses to stress are the result of a complex interaction between genetics and previous experiences of the animals, but such relationships are not fully understood at this time (Probst et al., 2014).

Of the animals displaying MS ≥3, 50% were diagnosed as having FCS. In hogs, approximately 50% of the nonambulatory animals are considered fatigued (Ritter et al., 2009). It should be noted that of the 65,600 animals observed in the current study, only one animal was observed to be nonambulatory and the animal suffered from extreme fatigue. When compared with earlier observational reports of increased prevalence of cattle displaying signs of FCS, the syndrome does not seem to be as prevalent as previously reported, based on the results of this study (Edwards-Callaway, 2013; Grandin, 2013).

Inherently, there are limitations to any observational study. The use of subjective measurements (MS and clinical diagnoses) allows for differences in opinion as to what constitutes the different levels of mobility. However, the use of the same trained observer on each day and the use of a mobility scoring system and specific case definitions to define the clinical diagnosis categories help to eliminate some subjectivity. While the categories used to summarize clinical diagnoses of the abnormalities reported here are quite broad and animals entering the slaughter facility could have displayed more specific problems than the ones reported here (i.e., if a tumor affecting mobility was present on an animal's leg, the abnormality was classified as "poor conformation" and a comment was made to note the presence of the tumor), these case definitions capture the majority of pathologies that contribute to decreased mobility in fed cattle. Despite some limitations, observational research, including the current study, offers insight into issues that the industry encounters every day and serves as a platform upon which subsequent research can be based.

After the adverse mobility events occurred during the summer of 2013 (Thomson et al., 2015), slaughter facilities began revisiting strategies to improve mobility and protect the welfare of cattle presented for slaughter. Strategies implemented thus far include communicating with feedyards about incoming cattle conditions, making truck drivers and facility employees aware of the clinical signs of FCS, and contracting with feedyards which employ mitigation strategies such as regular exercise, early detection of heat stress, and low-stress-handling techniques (Siemens and Alexander, personal communication [Cargill Meat Solutions, Wichita, KS]). Identifying and implementing strategies to help reduce the variability of cattle sources, handling practices, and transport practices can lead to better health and well-being in all finished cattle transported to slaughter facilities.

CONCLUSION

The information reported here is novel in the finished beef cattle industry. A sample of such magnitude is difficult to find in the literature, and much information can be gleaned from the observations made in this study, including the contributions of different clinical abnormalities to the mobility status of cattle presented for slaughter. Measuring MS and identifying the possible causes of decreased mobility can help producers further up the transport chain understand which practices to implement that will promote better health and mobility of fed cattle presented to slaughter. For example, widespread use of mitigation strategies such as regular exercise and low-stress-handling techniques may help address the most common mobility issue encountered in this study (general stiffness), which is similar to the approach and strategies used to address the prevalence of FCS. Further research is needed to more fully explore the risk factors contributing to decreased mobility in commercial slaughter facilities, but observational studies such as the one described here are important steps for determining which environmental and pathophysiological conditions should be the focal point of such research.

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