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A. Roca
Iowa State University

A. K. Johnson
Iowa State University, johnsona@iastate.edu

L. A. Karriker
Iowa State University, karriker@iastate.edu

L. L. Timms
Iowa State University, ltimms@iastate.edu

C. E. Abell
DNA Genetics

See next page for additional authors

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Abstract

Lameness detection using objective behavioral parameters provides an opportunity for timely treatment which, in turn, could improve sow welfare and reduce economic expense. Therefore, the objectives of this study were to (1) determine sow posture frequencies and duration (2) ascertain the postural sequence and time when standing to lying and vice versa and (3) to record how long it took for sows to access feed when lameness was induced using a chemical synovitis model. Lameness was induced in 24 multiparous, non-pregnant, crossbred 22 Newsham, maternal-cull sows by injecting amphotericin B in the distal interphalangeal joint 23 space. The experimental design was a 3 (days) x 2 (rear feet) factorial arrangement where sow was the experimental unit. All sows were video recorded in their home pens continually over a 12-h period (0600 to 1800 h) on the sound day (1 d pre-induction), on the most lame day (1 d post-induction) and the resolution day (6 d post-induction). Three postures (standing, lying and sitting), an unknown category, three lying positions (lying left lateral, lying right lateral and lying sternal), time to change postures, the number of postures used in a behavioral sequence and time to reach feeder on the raised step were collected. Sows spent less time standing on the most lame day compared to sound and resolution days ($P < 0.05$). Sows performed fewer standing and sitting postural adjustments on the most lame day compared to the sound day ($P < 0.05$). Lame sows transitioned through fewer postures and moved more quickly through the standing to lying transition on the most lame day compared to sound and resolution days ($P < 0.05$). Sows had a higher percentage of time lying laterally on the most lame day compared to sound and resolution days regardless of which foot was injected ($P < 0.05$). There were no observed differences in time (s) for sows to reach the feeder over treatment days ($P > 0.05$). In conclusion, these results support the use of behavioral indicators as an objective tool for detecting sow lameness when 38 using this transient lameness model.

Keywords

Behavior, Lameness, Pig, Sow, Productive 39 Lifetime

Disciplines

Agriculture | Animal Sciences | Large or Food Animal and Equine Medicine | Veterinary Preventive Medicine, Epidemiology, and Public Health

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Authors
A. Roca, A. K. Johnson, L. A. Karriker, L. L. Timms, C. E. Abell, and K. J. Stalder

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How do sow postures change when lameness is induced using a chemical synovitis model?

A. Roca[a], A.K. Johnson[a,1], L.A. Karriker[b], L.L. Timms[a], C.E. Abell[c], K.J. Stalder[a]

[a]Department of Animal Science, Iowa State University, Ames, IA 50011, USA

[b]Swine Medicine Education Center, Department of Veterinary Diagnostic and Production Animal Medicine, Iowa State University, 1600 South 16th St., Ames, IA 50011, USA

[c]DNA Genetics, 2415 13th St., Columbus, NE 68601, USA

[1]Correspondence to: 2356-F Kildee Hall, ISU, Ames, IA, 50021, USA. Tel.: + 1 515-294 2098; fax: + 1 515 294 4471. *E-mail address*: johnsona@iastate.edu (A.K. Johnson).

ABSTRACT: Lameness detection using objective behavioral parameters provides an opportunity for timely treatment which, in turn, could improve sow welfare and reduce economic expense. Therefore, the objectives of this study were to (1) determine sow posture frequencies and duration (2) ascertain the postural sequence and time when standing to lying and vice versa and (3) to record how long it took for sows to access feed when lameness was induced using a chemical synovitis model. Lameness was induced in 24 multiparous, non-pregnant, crossbred Newsham, maternal-cull sows by injecting amphotericin B in the distal interphalangeal joint space. The experimental design was a 3 (days) x 2 (rear feet) factorial arrangement where sow was the experimental unit. All sows were video recorded in their home pens continually over a 12-h period (0600 to 1800 h) on the sound day (1 d pre-induction), on the most lame day (1 d post-induction) and the resolution day (6 d post-induction). Three postures (standing, lying and sitting), an unknown category, three lying positions (lying left lateral, lying right lateral and lying sternal), time to change postures, the number of postures used in a behavioral sequence and time to reach feeder on the raised step were collected. Sows spent less time standing on the most lame day compared to sound and resolution days ($P < 0.05$). Sows performed fewer standing and sitting postural adjustments on the most lame day compared to the sound day ($P < 0.05$). Lame sows transitioned through fewer postures and moved more quickly through the standing to lying transition on the most lame day compared to sound and resolution days ($P < 0.05$). Sows had a higher percentage of time lying laterally on the most lame day compared to sound and resolution days regardless of which foot was injected ($P < 0.05$). There were no observed differences in time (s) for sows to reach the feeder over treatment days ($P > 0.05$). In conclusion, these results support the use of behavioral indicators as an objective tool for detecting sow lameness when using this transient lameness model.

Key Words: Behavior, Lameness, Pig, Sow, Productive Lifetime

1. Introduction

The United States Department of Agriculture reported that lameness was the fifth reason producers cull gilts and sows from the breeding herd (USDA, 2012). Lameness can negatively affect animal welfare (Heinonen et al., 2013), economical return due to reduced longevity and increased replacement rates (Sonderman et al., 2009; Stalder et al., 2004). Naturally occurring lameness may result in wide variations of sow behavioral responses (i.e. the time spent lying or the number of times a sow changes their postures) based on the severity, location and type of injury (Parsons et al., 2015), and this can make early identification of lameness on farm challenging to the caretaker. In the U.S., the main lameness detection tool on farm are subjective standing and walking gait score analysis, so U.S. swine producers continue to fund research on sow lameness with an emphasis on identifying novel but objective on-farm tools that can assist them in identifying and treating lameness (NPB, 2016).

To address the concern relating to an unknown lameness etiology when testing novel lameness tools, Karriker et al. (2013) validated that amphotericin B induced a predictable, acute and transient sow lameness model when injected in the distal interphalangeal joint space. Hence, this chemically induced synovitis model provides a known population status regarding lameness severity and duration that enables the testing of lameness detection tools. Previous kinematic and mechanical nociceptive threshold tests (Mohling et al., 2014a, 2014b) and biomechanic tests (Karriker et al., 2013; Mohling et al., 2014a; Sun et al., 2011) have been validated using this chemical synovitis model. Pairis-Garcia et al. (2015) and Parsons et al. (2015) validated standing and lying sow frequencies using this model with and without the application of non-steroidal inflammatory drugs (NSAID). However the percentage of time a sow is engaged in standing, lying and sitting and how this model changes a sow's ability to control her movements when moving through postural sequences without NSAID usage has yet to be quantified. Therefore, the objectives of this study were to (1) determine sow posture frequencies and duration (2) ascertain the postural sequence and time when standing to lying and vice versa and (3) to record how long it took for sows to access feed when lameness was induced using a chemical synovitis model.

2. Materials and methods

The protocol for this study was approved by the Iowa State University Institutional Animal Care and Use Committee. Sows' were cared for in accordance with the United States Animal Welfare Act and the *Guide for the Care and Use of Laboratory Animals, 8th Edition*. Lameness induction resulted in transient pain states but the experiment was designed to allow each sow to serve as her own control, thus reducing the total number of sows required whilst maintaining sample sizes large enough to achieve statistical power. Investigators established humane end-point criteria in which any sow that was unable to access water for 12 h, access food for 24 h or progressed to non-weight bearing lameness for 48 h was removed from the study and humanely euthanized. No sows met these criteria during this study. All sows were acclimated to housing and handling for 7 d prior to trial initiation (Pairis-Garcia et al., 2014).

2.1. *Animals and housing*

Twenty-four multiparous (mean parity 4; range 2 to 7), non-pregnant crossbred Newsham maternal line, cull sows were obtained from a commercial farm in Iowa (bodyweight 200.4 ± 8.4

kg). All sows were physically examined prior to selection by a veterinarian in charge with sow lameness expertise. Sows selected for the study were categorized as non-lame (i.e. placed weight evenly on all four feet). Physical examination and lameness evaluation were conducted between each round during the trial to confirm no observable residual lameness was present. Lameness evaluation included the ability of the sow to walk 10-m over a concrete floor with weight placed on all four feet. Each sow received a lameness score (0 = normal gait, sow had no difficulty walking and placed even weight on all four legs, 1 = abnormal gait, the sow had a shortened stride and/or a pronounced swagger of the caudal part of the body when walking and 3 = severe abnormal gait, there was no weight-bearing on the affected limb, or the sow was unable to walk). No sows on trial showed any signs of residual lameness and were classified as non-lame. To avoid confounding injury due to aggression, each sow was housed in an individual home pen; however, sows could see, smell, hear and have nose-to-nose contact with other sows. Each home pen measured 3.7 length × 1.4 width × 1.2 height m and had a solid concrete floor with a boar rubber mat by FarmerBoy (2.4 length × 1.4 width m x 1.9 cm depth with a 1.4 cm perforation size; Meyerstown, PA, USA). Metal fences (1.2 height × 0.8 width m) were affixed to the end of each home pen. Each home pen was provided with chains and plastic toys attached to the home pen gates. Sows were provided *ad libitum* access to water via one nipple water drinker (Model 65; Trojan Specialty Products, Dodge City, KS, USA) that was positioned over a grate. Sows were hand-fed in their home pens, on a raised step (1.4 length x 0.6 width x 0.2 H m) receiving 2.3 kg of feed in the morning and 0.5 kg in the afternoon. The ration was a custom-mixed diet of 14.8% Crude Protein Total Mixed Ration composed of ground corn, soybeans, and nutrients formulated according to Swine NRC guidelines (1998) with no antimicrobials. FDA approved Matrix® (0.22 % Altrenogest; Intervet/Schering-Plough, Milsboro, USA; DE-Dose: 6.8 ml-15 mg) was added to 1 kg of feed daily to prevent estrus initiation. Facilities and sows were inspected by caretakers at 0730 and 1530 daily at the time sows were fed.

2.2. *Induction of lameness*

Feed and water was withheld 18- and 1 h respectively prior to anesthesia to reduce vomiting and aspiration risk. Sows were restrained in a standing position using a snare and then anesthetized using xylazine (4.4 mg/kg; Anased®, Lloyd Laboratories, Shenandoah, IA, USA), ketamine HCl (2.2 mg/kg; Ketaset®, Fort Dodge Animal Health, Wyeth, Madison, NJ, USA), and Telazol® (4.4 mg/kg; tiletamine HCl and Zolazepam HCl as an equal weight mixture Fort Dodge Animal Health, Wyeth, Madison, NJ, USA) administered intramuscularly. Anesthesia dosages were based on recommendations by St-Jean and Anderson (2006). Palpebral reflex was evaluated to confirm insensibility after anesthesia administration. After insensibility was established, the toes on the assigned foot were washed with water to remove obvious fecal contamination, and washed for a further 3 min with iodine based surgical scrub (Operand®, Aplicare Inc., Branford, CT, USA) using 10 x 10 cm sterile gauze pad. The foot was then rinsed with 70% isopropyl alcohol until no evidence of the surgical scrub remained. After cleaning, 10 mg amphotericin B (X-gen Pharmaceuticals, Inc., Big Flats, NY, USA) was injected into the distal inter-phalangeal joint (intra-articular space) of both toes in the assigned foot (Karriker et al., 2013). Throughout anesthesia, respiratory rate was measured by calculating chest evaluations, and rectal temperature were monitored every 15 min until sows returned to a standing posture unaided.

2.3. *Experimental design*

The experimental design was a 3 (days) x 2 (rear feet) factorial arrangement where sow was the experimental unit. This experimental design provided control of intra- and inter-animal variations in behavioral responses and limited the number of sows required. Sows were randomly allocated to one rear foot for first lameness induction. After completion of the first round, sows were given a 7 d rest period and then the procedures were repeated with the opposite rear foot induced for the second round. Three ***days*** were compared, ***sound*** (defined as 1 d pre-induction), ***most lame*** (defined as 1 d post-induction) and ***resolution*** (defined as 6 d post-induction), and two rear ***feet***: left rear vs. right rear foot. The treatment days of sound, most lame and resolution were selected based on previous experience with the amphotericin B lameness induction model (Karriker et al., 2013; Mohling et al., 2014a, 2014b).

2.4. *Behavioral acquisition*

Sows were video recorded in their home pens continually over a 12 h period (0600 to 1800 h) on sound, most lame and resolution days. Video was recorded using **one** 12 V color Close Circuit Television (CCTV) camera (Model WV-CP484, Matsushita Co Ltd, Japan) positioned centrally (2.9 m from pen front) using an elbow bracket at a height of 2.8 m from the floor. Video was captured digitally utilizing a Noldus portable lab (Noldus Information Technology, Wageningen, The Netherlands). Panasonic cameras (WV-CP484, Kadoma, Japan) were fed into a multiplexer, which allowed the image to be recorded using a PC with HandiAvi (v4.3, Anderson's AZcendant Software, Tempe, AZ, USA) at 30 frames/s. A computer screen was used to view the video output to ensure picture clarity and camera positioning prior to each behavioral recording session. All data were collected by two trained observers blind to treatment using the Observer software (The Observer, Version 5.0.25, Noldus Information Technology, Wageningen, The Netherlands). Inter-reliability training on a 2 h sample video was conducted to ensure a 98% agreement between observers. For the remaining data, each observer was assigned twelve sows to score for the study duration. Data was collected continually (Martin and Bateson, 2007). Three postures and three lying positions were collected (Table 1). A sow that could not be seen was recorded as unknown. Time to change postures (s) was defined as a sow moving from a lying- to standing posture or from standing- to a lying posture. The behavioral sequence was defined as the number of postural changes that occurred between a sow lying- to standing or standing to lying. Time for the sow to reach the raised concrete step began when feed was placed onto the raised concrete step and ended when the back of the sows head including her ears were over the raised concrete step (1.4 L x 0.6 W x 0.2 H m).

2.5. ***Statistical analysis***

Data were analyzed using SAS software, version 9.3 (SAS Inst. Inc., Cary, NC, USA). Data were analyzed for normality by plotting a predicted residual plot and a quantile-quantile plot using PROC UNIVARIATE. A generalized linear mixed model was fit (GLIMMIX) with a Beta distribution to determine percentage of time spent in standing, lying and sitting postures between day (sounds, most lame and resolution), with a covariate of sow body weight, and a random effect of sow within day and treatment (right or left foot lame). The postural adjustment frequencies postures between day was analyzed using a generalized linear mixed model (GLIMMIX) with a poisson distribution, with a covariate of sow body weight, and a random effect of sow within day and treatment (right or left foot lame). The behavioral sequence for a sow to go from a standing to lying or lying to standing was evaluated using two variables. The first variable was the duration of time (s) for a sow to go from a lying posture to a standing posture or from standing to lying posture. A generalized linear mixed model (MIXED) was fit with a Poisson distribution using a covariate of sow body weight, the 2-way interaction between sequence (lying to standing or standing to lying) and day, and a random effect of sow within day. The second variable was the number of posture changes that occurred before a sow went from a lying to standing or standing to lying position. The generalized linear mixed model was fit (GLIMMIX) with a Poisson distribution. The model included a covariate for sow body weight, the 2-way interaction between sequence and day, and a random effect of sow within day. No interactions were significant and these were removed from the final model. A generalized linear mixed model was fit (MIXED) for sow time to get to the feeder. The model included a covariate of sow body weight, and a random effect of sow within day by treatment. A P value of ≤ 0.05 was considered to be significant. Postural adjustment frequencies within pen location was evaluated using a generalized linear mixed model (GLIMMIX) with a Poisson distribution and the 3-way interaction between day, posture, and location, a covariate of sow body weight, and a random effect of sow within day and treatment.

3. Results

3.1. **Sow postures and postural adjustment frequencies**

The percentage of time spent standing was less, but lying increased on the most lame day compared to sound and resolution days. The percentage of sitting did not differ over treatment days ($P > 0.05$). Sows performed fewer standing and sitting postural adjustment frequencies on the most lame- compared to sound and resolution days. Sows had fewer lying postural adjustment frequencies on most lame compared to the resolution day ($P < 0.05$; Table 2).

3.2. Behavioral sequence (number of posture changes) and time to change posture

On the most lame day, sows transitioned through fewer postures when moving from standing to lying (sound 6.2 ± 0.6; most lame 3.5 ± 0.3 ; resolution 6.8 ± 0.6 number of postures), and moved from a standing to lying posture quicker (min) when most lame compared to sound and resolution days ($P < 0.05$; Figure 1). There was no observed difference in the number of postures (sound 4.9 0.5; most lame 4.3 ± 0.4; resolution 5.3 ±0.5 number of postures) or time (min) for sows to change from lying to standing over treatment days ($P > 0.05$; Figure 1).

3.3. Sow lying posture

There was no observed difference between the percentage of time sows laid laterally or sternally between sound- and resolution days ($P > 0.05$). Sows spent a greater percentage of time lying laterally when most lame regardless of which foot was injected ($P < 0.05$; Table 3).

3.4. Time to reach the feeder

There was no observed difference in time (s) for sows to reach the feeder when feed was presented ($P = 0.50$) between the sound- (0.27 ± 1.48 s), most lame- (2.25 ± 1.48 s) and resolution days (2.54 ± 1.48 s).

4. Discussion

In agreement with previous studies, the chemical synovitis model produced a reliable and predictable rear foot sow lameness that resolved within 7 to 10 d (Karriker et al., 2013; Mohling et al., 2014a, 2014b; Pairis-Garcia et al., 2014, 2015; Tapper et al., 2013). When most lame, sows stood about 69% less compared to a sound state. These findings are in agreement with previous work that reported a 40 to 79 % reduction in standing for lame sows (Buddle et al., 1994; Fitzgerald et al., 2012; Grégoire et al., 2013; Valros et al., 2009). Hence, increased time lying may be a sensitive behavioral indicator that a sow is becoming, or has become lame.

Lame sows performed 74% fewer standing postural adjustment frequencies compared to sound. These findings are in agreement with Enokida et al. (2011) who reported a lower standing frequency in sows that had a higher prevalence of total lesion toe score. When sows transitioned from standing to lying on most lame, the number of postures was reduced from about seven to four. In addition, elapsed time between moving through these postural transitions was also reduced by 1,454 s. This agrees with Calderón Díaz et al. (2014) who reported a reduction in latency to lie down after standing from ~1,230 to 846 s. In the present study, we did not investigate the speed of a sow transitioning from standing to lying and any secondary effects, for example the presence of wounds, scratches or lesions. Future studies should ascertain any secondary animal-based measures as it relates to the speed of changing from a standing to lying posture over different lameness severities. In addition, it would be useful to collect other animal based measures to ascertain if the sow has inadvertently caused injury to herself. Watching a sow transition from standing to lying, counting the postures performed and timing this process could be a sensitive behavioral indicator that a sow is becoming, or has become lame.

Sows did not reduce their required time to reach the feeder when feed was presented. Reasons for these findings may be that (1) sows were aware in advance that food was coming due to lights on, people in, and sounds at the feed bin, providing them time to reach the feeder location before food was presented, (2) sows maintained a high motivation to eat even when most lame, (3) there was no competition (housed singularly) and/or (4) feed was presented on a raised step close to where they sat/lay. Previous studies with sows experiencing naturally occurring lameness have reported a reduction in feeding and drinking frequencies, bouts and duration (Buddle et al., 1994; Grégoire et al., 2013). Hence, with the housing used in this study we cannot suggest that time to reach the feed is a sensitive behavioral indicator that a sow is becoming, or has become lame.

Sows in the present study did not express a side lying preference; however, they did prefer to lie lateral when most lame compared to sound and resolution. This is in agreement with Parsons et al. (2015) whom using this same model also reported that most lame sows choose to lie laterally. Future lameness work should focus in naturally occurring lameness to determine if the amount of time lying in lateral versus sternal positions are sensitive behavioral lameness indicators. However, due to the chemical synovitis model used in this study, we cannot suggest that lying side preference are sensitive behavioral indicators that a sow is becoming, or has become lame.

5. Conclusion

In conclusion, results support the use of specific behavioral indicators as a tool for detecting sow lameness when using a chemical synovitis model. Promising postures include time spent lying, standing postural adjustment frequencies and number of postures and time taken when moving from a standing to lying posture.

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Highlights

- Sows spend more time lying when lame.
- Sows moved from standing to lying quicker and move through fewer postures when lame.
- Observing a sow moving from standing to lying and timing how quickly she lies down may serve as a good behavioral predictor of lameness severity.

Table 1. Postural measures from 24 multiparous, crossbred cull sows in their home pen.

Measure	**Definition**
Posture, %, No.	
Standing	Assuming or maintaining an upright position on extended legs. Include all actions where all four feet are in contact with the ground.
Lying	Lying with the majority of the sternum contacting the ground or lying with either the left or right side of body in contact with ground.
Sitting	Posterior portion of the sow’s body is in contact with the pen or the ground of the pen. Anterior portion of the body is supported by the front two legs in an extension position.
Lying position, %	
Lying left lateral	Majority (>50%) of the left side of the body in contact with the ground.
Lying right lateral	Majority (>50%) of the right side of the body in contact with the ground.
Lying sternal	Majority (>50%) of the sternum in contact with the ground.
Unknown, %, No.	Sow was out of her pen and could not be seen.

[1]% = Percent of time spent performing posture; No. = number of times performing posture.

Table 2. Percentage of time and number of postural adjustment frequencies engaged in standing, lying or sitting by stage of lameness LSMeans (±SE) from a study evaluating 24 multi-parity non-pregnant crossbred Newsham maternal line, cull sows[1,2]

	Stage of lameness[3]		
	Sound	**Most lame**	**Resolution**
Posture, %			
Standing	33.1 ± 1.7[a]	10.1 ± 1.1[b]	25.9 ± 0.6[c]
Lying	55.8 ± 1.8[a]	82.7 ± 1.3[b]	67.2 ± 1.7[c]
Sitting	2.1 ± 0.5[a]	1.7 ± 0.5[a]	2.7 ± 0.6[a]
Unknown	9.0 ± 1.1	5.4 ± 0.8	4.2 ± 0.7
Posture, No.			
Standing	42.54 ± 5.39[a]	10.98 ± 1.34[b]	31.01 ± 3.94[a]
Lying	4.10 ± 0.53[ab]	3.36 ± 0.42[a]	4.80 ± 0.62[b]
Sitting	1.95 ± 0.26[a]	0.95 ± 0.13[b]	1.79 ± 0.24[a]
Unknown	0.42 ± 0.07	0.26 ± 0.04	0.24 ± 0.04

[1]Twenty-four multiparous (mean parity 4; range 2 to 7), non-pregnant crossbred Newsham maternal line, cull sows were obtained from a commercial farm in Iowa (bodyweight 200.4 ± 8.4 kg).

[2]Lameness induced by injecting amphotericin B into the distal interphalangeal joint of the sow (Karriker et al., 2013).

[3]Day before lameness induction sound (defined as 1-d pre-induction), most lame (defined as 1-d post-induction) and resolution (defined as 6-d post-induction).

[abc]Denotes different superscripts within a row indicate a difference between means ($P < 0.05$).

Table 3. Percentage of time spent in three lying postures by stage of lameness LSMeans (±SE) from a study evaluating 24 multi-parity non-pregnant crossbred Newsham maternal line, cull sows[1,2]:

	Left rear lame foot			Right rear lame foot[3]		
Position, %	**Sound[3]**	**Most lame**	**Resolution**	**Sound**	**Most lame**	**Res**
Lying left lateral	10.3 ± 1.9[a]	29.5 ± 2.8[b]	9.7 ± 1.9[a]	11.2 ± 2.0[a]	36.5 ± 2.9[b]	13.
Lying right lateral	12.8 ± 2.1[a]	34.1 ± 2.9[b]	14.9 ± 2.3[a]	13.0 ± 2.2[a]	21.2 ± 2.5[b]	15.
Lying sternal	32.4 ± 3.0[a]	19.0 ± 2.4[b]	39.9 ± 3.1[a]	32.1 ± 3.0[a]	25.1 ± 2.6[b]	40.
Standing and sitting[5]	44.5 ± 3.2[a]	17.3 ± 2.3[b]	35.6 ± 3.1[c]	43.8 ± 3.2[a]	17.3 ± 2.3[b]	30.

[1]Twenty-four multiparous (mean parity 4; range 2 to 7), non-pregnant crossbred Newsham maternal line, cull sows were obtained from a commercial farm in Iowa (bodyweight 200.4 ± 8.4 kg).

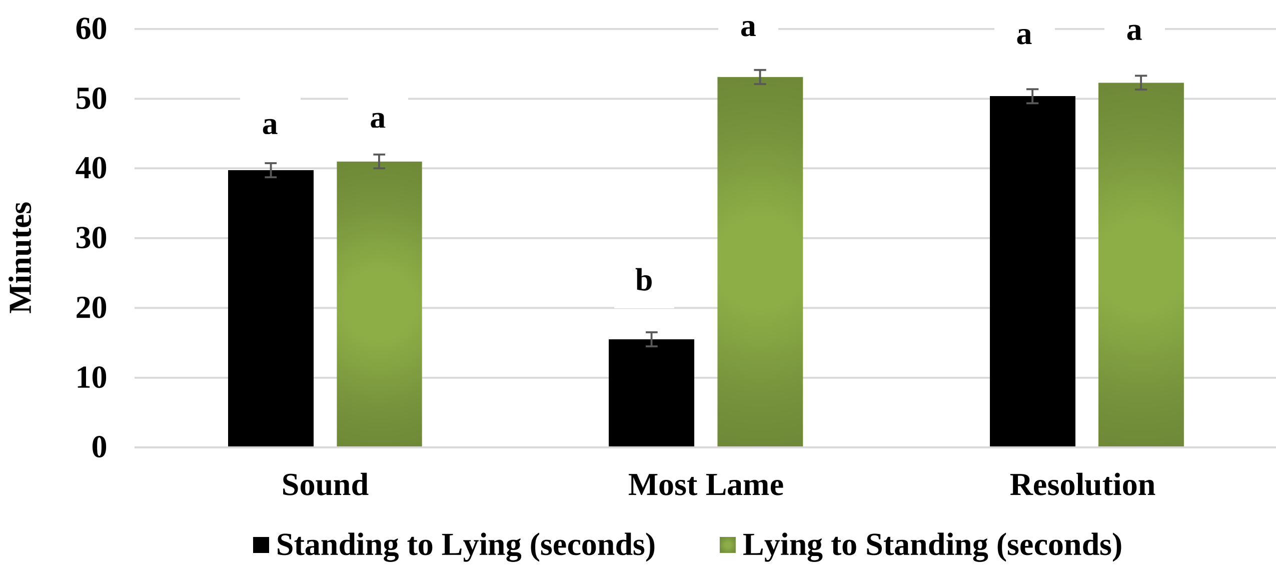
[2]Lameness induced by injecting amphotericin B into the distal interphalangeal joint of the sow (Karriker et al., 2013).

[3]Day before lameness induction sound (defined as 1-d pre-induction), most lame (defined as 1-d post-induction) and resolution (defined as 6-d post-induction).

[4]Standing and sitting were summed to equate the remaining sow time budget.

[abc]Denotes different superscripts within a row and treatment foot indicate a difference between means ($P < 0.05$).

Figure 1. LSmeans (±SE) of elapsed time (minutes) for sows to change from standing to lying or lying to standing when sound and induced lame for 24 multi-parity non-pregnant crossbred Newsham maternal line, cull sows[1, 2]



[1]Lameness induced by injecting amphotericin B into the distal interphalangeal joint of the sow (Karriker et al., 2013).

[2]Day before lameness induction sound (defined as 1-d pre-induction), most lame (defined as 1-d post-induction) and resolution (defined as 6-d post-induction).

[ab]Denotes different superscripts between columns indicate a difference between means ($P < 0.05$).