Validation of a lameness model in sows using physiological and mechanical measurements

L. A. Karriker, C. E. Abell, M. D. Pairis-Garcia, W. A. Holt, G. Sun, J. F. Coetzee, A. K. Johnson, S. J. Hoff and K. J. Stalder

J ANIM SCI 2013, 91:130-136.
doi: 10.2527/jas.2011-4994 originally published online October 9, 2012

Validation of a lameness model in sows using physiological and mechanical measurements[1]

L. A. Karriker,* C. E. Abell,† M. D. Pairis-Garcia,† W. A. Holt,* G. Sun,‡ J. F. Coetzee,§ A. K. Johnson,†[2] S. J. Hoff,‡ and K. J. Stalder†

*Swine Medicine Education Center, College of Veterinary Medicine; †Department of Animal Science; ‡Department of Agricultural and Biosystems Engineering; and §Cyclone Analyte Detection Service, College of Veterinary Medicine, Iowa State University, Ames 50011

ABSTRACT: The objective of this study was to develop a validated, transient, chemically induced lameness model in sows using subjective and objective lameness detection tools. Experiment 1 determined an effective joint injection technique based on volume and placement of dye using feet collected from 9 finisher pigs and 10 multiparity cull sow carcasses. Experiment 2 confirmed the injection technique in live animals and produced a transient clinical lameness in 4 anesthetized sows injected with amphotericin B (15 mg/mL) in the distal interphalangeal joints of the claw. Clinical lameness was assessed by a categorical lameness scoring system, and a postmortem visual confirmation of joint injection technique was obtained. In Exp. 3, 6 sows were injected with 0, 10, or 15 mg/mL amphotericin B in either the left or right hind foot and were monitored until clinical resolution. Treated sows demonstrated elevated clinical lameness scores. These changes resolved by 7 d after lameness induction. Control sows injected with sterile saline developed a clinical lameness score of 0.5, which resolved 72 h post injection. In Exp. 4, 36 sows were injected with 10 mg/mL amphotericin B in 1 of 4 injection sites (left front claws, right front claws, left rear claws, and right rear claws). All injected sows exhibited a decrease in maximum pressure, stance time, and number of sensors activated on the GaitFour ($P < 0.05$) sensor system. A static force plate also demonstrated a decrease in weight (kg) being placed on the injected foot when all feet were injected ($P \leq 0.05$). Injection of amphotericin B induced a predictable acute lameness that resolved spontaneously and is an effective method to model lameness in sows.

Key words: amphotericin B, lameness, pain, sow, welfare

J. Anim. Sci. 2013.91:130–136
doi:10.2527/jas2011-4994

INTRODUCTION

Lameness associated with painful joint lesions has been identified as a welfare challenge for confined sows (Elmore et al., 2010). Lameness or feet and leg problems was ranked as the third greatest reason for culling sows, comprising 15% of the culls marketed in the United States (Schenk et al., 2010). Feet and leg problems were identified as the most common involuntary reason for culling sows (Stalder et al., 2004) and also have been associated with several variables that result in poor reproductive performance, including decreased litter size, poor farrowing performance, and decreased sow longevity (Engblom et al., 2008; Anil et al., 2009).

There are no analgesic drugs approved for use in swine by the U.S. Food and Drug Administration (**FDA**). This is due to the lack of objective assessment tools for pain, which are a requirement according to FDA Guidance Document 123 (USDA, 2008). Developing objective assessment tools requires populations of known status, specifically painful and nonpainful. Lameness is an externally observable manifestation of joint pain. Three successful lameness induction models using amphotericin B have demonstrated a predictable, acute synovitis in cattle (Kotschwar et al., 2009; Schulz et al., 2011) and horses (Bowman et al., 1983), with no long-term residual effects observed. Neither a procedure to inject the distal interphalangeal joints nor

[1]This research was funded by the National Pork Board (09-073). The contributions of Allison Meiszberg and Lori Layman for animal management and data collection are acknowledged and greatly appreciated.

[2]Corresponding author: johnsona@iastate.edu

Received December 5, 2011.
Accepted August 30, 2012.

the effects of intra-articular amphotericin B in swine have been described in the scientific literature. Therefore, the objective of this study was to develop a validated, transient, chemically induced lameness model in sows using subjective and objective lameness detection tools.

MATERIALS AND METHODS

Sows were housed and fed individually according to the Swine Care and Use Guidelines (Federation of Animal Science Society, 1999), and protocols were reviewed and approved by the Iowa State University Animal Care and Use Committee before conducting experimental work. Humane end point criteria were established because at the onset of the experiment, lameness severity and duration resulting from injecting amphotericin B into the distal interphalangeal joints in swine were unknown. The investigators established humane end point criteria so that any sow that progressed to non-weight-bearing lameness for 48 h or was unable to access water for >12 h or feed for >24 h was removed from the study and humanely euthanized.

Amphotericin B (X-Gen Pharmaceuticals, Inc., Big Flats, NY) was obtained as a sterile, nonpyrogenic, lyophilized powder containing 50 mg of amphotericin B and 41 mg of sodium desoxycholate with 20.2 mg of sodium phosphate as buffer. The powder was reconstituted using sterile water to a concentration of 15 or 10 mg/mL as prescribed by the respective experiment. When concentrated to 15 mg/mL, the resulting solution was cloudy and required almost constant agitation to maintain the solution. The 10 mg/mL concentration was dark yellow, but not cloudy, and did not require constant agitation for the amphotericin B to remain suspended in the saline. Because of these observed differences in the chemicophysical properties, the goal of model development was to use the less concentrated of the 2 that created lameness.

Experiment 1: Determining Appropriate Injection Technique

Ten feet were disarticulated at the metacarpophalangeal joint from multiparity commercial sow carcasses obtained at harvest, and 9 feet from the carcasses of 21-wk-old finishing pigs were obtained from a local harvest plant postmortem. Claws were placed in extension, and the distal interphalangeal joint was identified by palpation (both medial and lateral claws). The needle was inserted on the dorsal surface at the midline of the claw. Needle placement was confirmed by joint fluid aspiration combined with injection of a FDA-approved meat marking dye (Hantover, Inc., Kansas City, MO; catalog number 40328). Beginning with a 20-gauge (**ga**) needle and 2 mL of fluid volume, subsequently smaller needles and fluid volumes were used. This methodology was continued until no leaking was observed from the injection site. It was determined that a 23-ga needle and 1-mL injection volume accomplished repeatable injection results. Smaller needle sizes and injection volumes were considered but arbitrarily rejected as impractical because of amphotericin B viscosity and formulation. The injection position was recorded using digital photography. All feet were frozen at −20°C for 24 h, and each claw was sagittally sectioned. Sections were digitally photographed to confirm the location of the injected dye in the distal interphalangeal joints.

Experiment 2: Intra-articular Injection in Live Animals

Four multiparity commercial cull sows with no observable clinical lameness signs were used in this trial. Clinical experience by the investigators suggested that injection at the distal interphalangeal joint in nonanesthetized sows was impractical, and anesthesia was indicated to ensure model repeatability. After being restrained by a humane hog snare, sows were anesthetized by administering the following combination intramuscularly: xylazine (4.4 mg/kg BW; Anased, Lloyd Laboratories, Shenandoah, IA), Ketamine HCl (2.2 mg/kg BW; Ketaset, Wyeth, Madison, NJ), and tiletamine HCl and zolazepam HCl (4.4 mg/kg BW) used in combination (Telazol; Wyeth). During anesthesia, the entire claw was washed with mild soap and water to remove obvious organic material and fecal contamination. After this wash, the treated foot was scrubbed for 5 min with 10% iodine-based surgical solution (Operand, Aplicare Inc., Branford, CT) using 10 × 10 cm sterile gauze pads. The foot was then rinsed with 70% isopropyl alcohol until surgical scrub was removed. Approximately 10 min after anesthesia onset, sows were positioned in lateral recumbency, and injection sites were scrubbed a second time using the previously described procedures. After the second scrub, 0.8 mL of a 15 mg/mL amphotericin B (X-Gen Pharmaceuticals, Inc.) solution and 0.2 mL of meat marking dye (Hantover, Inc., catalog number 40328) solution were mixed and injected in the intra-articular space of the left rear, medial, distal interphalangeal joint.

Throughout anesthesia, heart rate (physical detection with the hand placed at third to fourth rib), respiratory rate (chest elevations resulting from inspiratory effort for 15 s), and rectal temperature were monitored every 15 min until sows returned to a sternal position unaided. At 24 h after lameness induction, lameness was subjectively confirmed using a 5-point scale adapted from Crawford et al. (1991; Table 1). Once a sow exhibited a subjective lameness score ≥ 2, sows were humanely eu-

thanized with a captive bolt gun (Accles and Shelvoke Ltd., West Midlands, UK). The injected foot was excised at the level of the hock and frozen for further sectioning and evaluation as previously outlined in Exp. 1.

Experiment 3: Response to Amphotericin B Injection in Live Sows

Six multiparity, clinically sound commercial sows were used. Sows were randomly allotted to 1 of 3 treatments at the initiation of anesthesia. Two sows received 1 mL of sterile saline control (**CO**), 2 sows received 1 mL of a 10 mg/mL amphotericin B concentrated solution (**LO**), and 2 sows received 1 mL of a 15 mg/mL solution (**HI**) injected in the intra-articular space of the left or right rear, medial, distal interphalangeal joint as outlined in Exp. 1. All joint injections occurred as sows were under general anesthesia by an intramuscular injection of half of the anesthetic dose used in Exp. 2 [xylazine (2.2 mg/kg BW; Anased, Lloyd Laboratories), ketamine HCl (1.1 mg/kg BW; Ketaset, Wyeth) and tiletamine HCl and zolazepam HCl (2.2 mg/kg BW) used in combination (Telazol, Wyeth)] to reduce recovery time. Preparation of the injection site and postinduction sow monitoring followed the same protocols as used in Exp. 2.

Lameness Scoring

Immediately before anesthesia, sow lameness was assessed individually by 2 observers blinded to the treatment as sows were walking and standing, using the 5-point scale (Table 1). Individual sow lameness assessment evaluations continued daily until lameness resolved. Observers were trained with this scoring system by reviewing examples of each score with both visual and descriptive training material before assessing individual sows. This scoring system was chosen because it was previously used in an amphotericin B–induced model of lameness in ponies that monitored for resolution of the effect (Crawford et al., 1991).

Experiment 4: Characterization of Lameness Model

In group 1 a total of 24 multiparity commercial sows (parities 1 to 4) with no observable clinical signs of lameness were used. Sows were randomly injected with 10 mg of amphotericin B in the distal interphalangeal joint of both claws in 1 of 4 injection sites: left front foot (**LF**), right front foot (**RF**), left rear foot (**LR**), and right rear foot (**RR**). In group 2 a total of 12 sows with no observable clinical signs of lameness were injected in the LR or RR sites only. All injections occurred using the anesthetic protocol as described in Exp. 3. Sows were assessed for lameness using 2 objective measurement tools: GaitFour (CIR Systems, Inc., Havertown, PA) and an Embedded Microcomputer Force Plate System (static force plate; see Sun et al., 2011). This process was repeated after a 13-d washout period on the remaining uninjected feet for group 1 sows and the alternate rear foot for group 2 sows. All sows appeared clinically sound and showed no signs of lameness from previous injection on day of second injection.

GaitFour Walkway System. To assess sow movement, a GaitFour pressure mat was used to measure maximum pressure (kg/cm^2), stride length (cm), stance time (s), activated sensor count, and stride time (s) per foot during walking. The pressure mat was installed on a level floor surface in the facility where experiments occurred. The electronic walkway was created by connecting multiple sensors pads. Each sensor pad was 61 cm^2 and contained 2,304 sensors. The sensors were activated by pressure. Maximum pressure was defined as the greatest amount of weight placed on a single foot. Stride length was measured as the distance between 2 consecutive footfalls from the same foot. Stance time was the duration of time the sensors were activated (pressure was applied to the mat) by a foot in a single stride. Stride time was defined as the time between 2 consecutive footfalls by the same foot.

The walkway system was connected to a laptop computer, and 2 digital video cameras (Victor Company of Japan, Yokohama, Japan) were placed on each end of the walkway to record sows as they walked across the walkway. GaitFour software was synchronized with a video recording the walk of each sow. Each sow walked across the pressure mat until 3 passes occurred without the sow stopping or running on the mat surface. The 3 walking passes per sow were recorded, and each pass

Table 1. Categorical 5-point scoring system used for subjective evaluation in studying induced lameness in sows[1]

Lameness score	Description
0	Sow moves freely and uses all 4 limbs and feet evenly
1	Sow shows weight-shifting activities away from affected limb upon standing but shows little or no lameness or limping when walking
2	Sow obviously shifts weight away from affected limb when standing and shows limping or adaptive behavior when walking (head bob, quickened step on affected limb)
3	Sow is reluctant to stand and/or walk, obvious limp and adaptive behaviors when walking
4	Sow is nonweight bearing on the affected limb when either standing or walking

[1]Adapted from Crawford et al. (1991).

included at least 2 strides. Footfalls were individually highlighted (identified using video if necessary), sorted by initial footfall time on the pressure mat, and saved as a completed walk with a unique file name. Data from completed walks were compiled by exporting into a spreadsheet for further analysis. Data were collected on **D-1** (day before joint injection), **D+1** (first day after joint injection), and **D+5** (fifth day postinjection) for all 36 sows. For the subset of 12 sows, data were also collected on **D+7** (seventh day postinjection)

Embedded Microcomputer Force Plate System. The Embedded Microcomputer Force Plate System (static force plate) was developed at Iowa State University to objectively identify sows that possess varying lameness severities (Sun et al., 2011). The static force plate was designed with a total dimension of 1,524 × 565 × 106 mm (length × width × height), with 6.4-mm-thick aluminum plating composing the top and bottom plates. A semiflexible epoxy (FlexCoat Vanberg Specialized Coatings, Lenexa, KS) was mixed with sand to mimic the floor type that a sow would stand on daily. Sows were walked into a standard gestation stall with the flooring replaced by the static force plate. Sows remained in the stall for 15 min. This plate measured each foot independently and was able to detect weight shifting activities as the sow was standing. Data were collected on D-1, D+1, and D+5 for all 36 sows. For the subset of 12 sows, data were also collected on D+7.

Statistical Analysis

Descriptive statistics were calculated from Exp. 1, 2, and 3 data. Statistical analysis of the differences between sound feet and the injected foot for GaitFour and static force plate parameters from Exp. 4 was conducted using SAS software (SAS Inst. Inc., Cary, NC). Footfall parameter measurements from the GaitFour were analyzed statistically as 3 paired ratios to evaluate sow locomotor compensation and lameness correction. The 3 ratios evaluated were lateral foot (i.e., if LR foot was injected, it was paired as a ratio to RR foot), same side (i.e., if LR foot was injected, it was paired as a ratio to the LF foot), and contralateral (i.e., if LR foot was injected, it was paired as a ratio to the RF foot). The ratios for total activated sensors, maximum pressure, stride length, stride time, and stance time were analyzed using the ProcMixed procedure from SAS. Days post lameness induction (**DPI**), treatment level (**trt**), and the interaction of DPI × trt were included as fixed effects, with sow as a random effect in the models used to analyze these data. Weight distribution on the static force plate for each individual foot (LF, RF, LR, and RR) was compared with the other noninjected feet and was analyzed using MIXED model procedures from SAS. Day of collection, day after lameness induction, treatment, and foot were included as fixed effects in the model, and sow within treatment by day of collection was included as a random effect. The injection number did not explain a significant amount of variation and so was removed from the model for both the static force plate and GaitFour analyses.

RESULTS

Experiment 1: Determining Appropriate Injection Technique

Within the range of needle gauges and fluid volumes tested, it was not possible to inject feet collected from 21-wk old finisher pigs without obvious back flow through the injection site and inconsistent fluid deposition into the distal interphalangeal joint space. Using feet collected from multiparity commercial cull sow carcasses, 22-mm, 23-ga needles with 1 mL of fluid volume resulted in accurate injection without dye flow back through the injection track. All frozen sagittal sections confirmed dye placement in the distal interphalangeal joint (Fig. 1).

Experiment 2: Intra-articular Injection in Live Animals

At the start of the experiment all sows received lameness score 0 and were determined to be clinically sound. The observed effects of anesthesia used on all sows persisted for <12 h. At 24 h postinjection, all sows received a lameness score of 2. Each sow was humanely euthanized once a lameness score of 2 was achieved, and postmortem sectioning of injected feet demonstrated dye in the distal interphalangeal joint in all cases (data not presented).

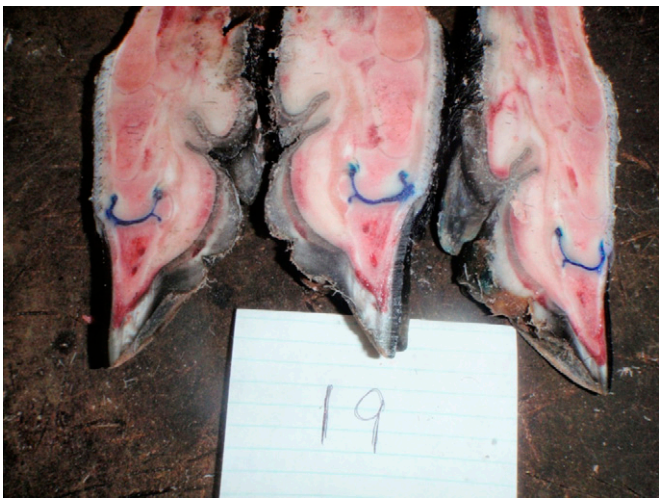

Figure 1. Evidence of correct injection placement in the distal interphalangeal joint of sow feet using a 23-guage needle and meat branding dye.

Experiment 3: Response to Amphotericin B Injection in Live Sows

At the start of the experiment all sows received lameness score 0 and were determined to be clinically sound. The anesthesia duration was shorter at the smaller anesthetic dose, with all sows recovering within 8 h. All injections (CO, LO, and HI) were administered successfully. The CO sow group achieved a maximum average lameness score of 0.5 at 24 h, which returned to 0 at 72 h after lameness induction. Lameness scores for LO and HI sows were numerically greater compared with CO sows for every time point until returning to baseline. The HI sow group returned to baseline 48 h earlier than the LO group; however, scores at 24 and 48 h after lameness induction were greater for HI sows than LO sows (Fig. 2).

Experiment 4: Characterization of Lameness Model

GaitFour Analysis. For the 24 sows (group 1) that were allotted randomly to have any 1 of 4 feet injected, there was a decrease ($P \leq 0.05$) in maximum pressure, stance time, and number of sensors activated for all ratios when comparing the sow before (D-1) and after (D+1) injection (Table 2). Results from the additional 12 sows (group 2) where only rear feet were injected were consistent with group 1. There was a decrease ($P \leq 0.05$) in stance time for all 3 paired ratios when comparing data collected on D-1 and D+1. There was a decrease ($P \leq 0.05$) in maximum pressure from the lateral side and contralateral foot paired ratios and a decrease ($P \leq 0.05$) in number of sensors for the contralateral side and same side paired ratios.

Static Force Plate Analysis. Table 3 shows the static force plate analysis results for groups 1 and 2, respective-

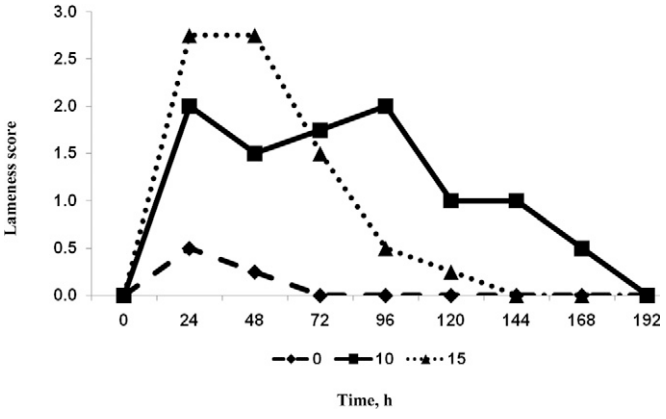

Figure 2. Average lameness scores by hours postinjection and dose in sows injected in the distal interphalangeal joint with amphotericin B in Exp. 3. Sows were subjectively evaluated for evidence of lameness using a 5-point scale adapted from Crawford et al. (1991).Control sows were injected with 1 mL of sterile saline control (diamonds); low sows were injected with 1 mL of 10 mg/mL amphotericin B (squares), and high sows were injected with 1 mL of 15 mg/mL amphotericin B (triangles). Time is defined as time after lameness induction.

Table 2. Means for the lateral side, same side, and contralateral ratios for footfall parameters adjusted for the effect of the sow and treatment on the day before joint injection (D-1) and the first day after joint injection (D+1) using the GaitFour system from sows injected with amphotericin B to induce lameness[1]

Ratio	Parameters[2]	D-1	D+1
Group 1 (24 sows)			
Lateral side	Maximum pressure	0.980 ± 0.030[a]	0.781 ± 0.030[b]
	Stride length	0.997 ± 0.002	0.992 ± 0.002
	Stance time	1.006 ± 0.026[a]	0.823 ± 0.026[b]
	Number of sensors	0.985 ± 0.027[a]	0.827 ± 0.027[b]
	Stride time	1.001 ± 0.023	1.003 ± 0.024
Same side	Maximum pressure	1.021 ± 0.025[a]	0.902 ± 0.025[b]
	Stride length	1.001 ± 0.002	1.002 ± 0.002
	Stance time	1.015 ± 0.027[a]	0.914 ± 0.027[b]
	Number of sensors	1.002 ± 0.021[a]	0.945 ± 0.021[b]
	Stride time	0.997 ± 0.020	0.999 ± 0.020
Contralateral	Maximum pressure	1.012 ± 0.019[a]	0.856 ± 0.019[b]
	Stride length	0.998 ± 0.003	0.993 ± 0.003
	Stance time	1.015 ± 0.024[a]	0.891 ± 0.025[b]
	Number of sensors	0.997 ± 0.017[a]	0.908 ± 0.017[b]
	Stride time	0.999 ± 0.021	1.002 ± 0.021
Group 2 (12 sows)			
Lateral side	Maximum pressure	0.950 ± 0.026[a]	0.688 ± 0.025[b]
	Stride length	1.000 ± 0.003	1.000 ± 0.003
	Stance time	1.007 ± 0.015[a]	0.797 ± 0.015[b]
	Number of sensors	0.959 ± 0.051	0.837 ± 0.049
	Stride time	0.990 ± 0.010	1.010 ± 0.010
Same side	Maximum pressure	0.707 ± 0.019[a]	0.520 ± 0.019[b]
	Stride length	0.995 ± 0.002	1.000 ± 0.002
	Stance time	0.933 ± 0.016[a]	0.888 ± 0.016[b]
	Number of sensors	0.772 ± 0.019[a]	0.620 ± 0.019[b]
	Stride time	0.987 ± 0.010	1.008 ± 0.010
Contralateral	Maximum pressure	0.701 ± 0.033[a]	0.521 ± 0.032[b]
	Stride length	0.999 ± 0.003	1.000 ± 0.003
	Stance time	0.947 ± 0.013[a]	0.826 ± 0.013[b]
	Number of sensors	0.763 ± 0.016[a]	0.630 ± 0.015[b]
	Stride time	1.000 ± 0.010	1.007 ± 0.010

[a,b]Means within a row without a common superscript differ ($P < 0.05$).

[1]The lateral side ratio is defined as the value for the treated foot divided by the untreated foot lateral to the treated foot. For example, if the left front foot is treated, the right front foot is the untreated foot in the ratio. If the right front foot is treated, the left front foot is the untreated foot in the ratio. The same side ratio is defined as the value for the treated foot divided by the untreated foot anterior or posterior to the treated foot. For example, if the left front foot is treated, the left rear foot is the untreated foot in the ratio. If the right rear foot is treated, the right front foot is the untreated foot in the ratio. The contralateral ratio is defined as the value for the treated foot divided by the untreated foot anterior or posterior and lateral to the treated foot. For example, if the left front foot is treated, the right front foot is the untreated foot in the ratio. If the right front foot is treated, the left front foot is the untreated foot in the ratio. Sows were injected with 1 mL of 10 mg/mL amphotericin B.

[2]The GaitFour (CIR Systems, Inc., Havertown, PA) pressure mat measures footfall parameters using pressure-activated sensors. The maximum pressure is the largest amount of weight place on a single foot. Stride length is the distance between 2 consecutive footfalls from the same foot. Stance time is the time between 2 consecutive footfalls of the same foot when the sensors are activated (pressure is applied to the mat). Stride time is the time between 2 consecutive footfalls of the same foot. The number of sensors is the count of the sensors activated by each foot.

ly. For the group 1 sows, a difference ($P < 0.05$) between the weight being placed on the injected foot and the lateral foot on the day after lameness induction was observed regardless of the leg that was injected. This difference was still present on D+5 for sows injected on the RF, LR, and RR. The difference in the LF was resolved by the last day of data collection (D+5; Table 3). For the group 2 sows, which only included rear feet evaluation, injection of both rear feet revealed a change ($P < 0.05$) in weight being placed on the injected foot compared with the lateral foot on the day after lameness induction (D+1) and D+5. By D+7 (last day of data collection), lameness had resolved so that no weight difference ($P > 0.05$) between injected and noninjected feet was detected.

Table 3. Mean weight (kg) measured on each foot with the static force plate when sows were injected with amphotericin B to induce lameness[1]

Foot treated[2]	Foot	Mean weight (kg) D-1[3]	D+1[3]	D+5[3]	D+7[3]
Group 1 (24 sows)					
LF	LF	57.44 ± 2.67	36.85 ± 3.19[a]	58.17 ± 2.39	–
	RF	58.14 ± 2.67	68.86 ± 3.19[b]	62.16 ± 2.39	–
	LR	41.24 ± 2.67	41.67 ± 3.19	43.29 ± 2.39	–
	RR	43.50 ± 2.67	47.65 ± 3.19	45.40 ± 2.39	–
RF	LF	57.02 ± 2.31	67.21 ± 3.58[a]	58.40 ± 2.03[a]	–
	RF	58.38 ± 2.31	43.52 ± 3.58[b]	54.91 ± 2.03[b]	–
	LR	41.39 ± 2.31	37.16 ± 3.58	40.29 ± 2.03	–
	RR	44.72 ± 2.31	44.15 ± 3.58	42.78 ± 2.03	–
LR	LF	54.30 ± 1.94	55.78 ± 2.28	54.36 ± 2.46	–
	RF	57.59 ± 1.94	60.37 ± 2.28	58.84 ± 2.46	–
	LR	42.10 ± 1.94	25.54 ± 2.28[a]	37.18 ± 2.46[a]	–
	RR	42.01 ± 1.94	50.18 ± 2.28[b]	44.55 ± 2.46[b]	–
RR	LF	52.83 ± 2.78	55.33 ± 3.16	53.41 ± 2.84	–
	RF	57.19 ± 2.78	57.33 ± 3.16	56.69 ± 2.84	–
	LR	40.88 ± 2.78	49.50 ± 3.16[a]	43.64 ± 2.84[a]	–
	RR	41.67 ± 2.78	22.85 ± 3.16[b]	35.43 ± 2.84[b]	–
Group 2 (12 sows)					
LR	LF	54.38 ± 2.62	56.03 ± 2.62	57.24 ± 2.58	57.28 ± 2.63
	RF	58.28 ± 4.88	62.70 ± 4.87	60.33 ± 4.86	61.63 ± 4.88
	LR	39.60 ± 2.86	27.25 ± 2.85[a]	38.23 ± 2.82[a]	41.87 ± 2.88
	RR	41.36 ± 2.72	48.89 ± 2.72[b]	43.93 ± 2.71[b]	42.41 ± 2.72
RR	LF	58.54 ± 4.32	56.44 ± 4.31	55.78 ± 4.31	58.10 ± 4.35
	RF	62.68 ± 4.07	64.13 ± 4.06	61.53 ± 4.06	62.10 ± 4.08
	LR	45.96 ± 3.02	53.81 ± 3.02[a]	47.88 ± 3.01[a]	46.48 ± 3.06
	RR	45.22 ± 3.26	24.93 ± 3.25[b]	38.56 ± 3.25[b]	43.61 ± 3.28

[a,b]Means within a treated foot are compared with the lateral foot, and means without a common superscript differ ($P < 0.05$).

[1]The Embedded Microcomputer Force Plate System (static force plate) was developed at Iowa State University to objectively identify sows that possess varying lameness severities (Sun et al., 2011).

[2]LF = left front foot, RF = right front foot, LR = left rear foot, and RR = right rear foot.

[3]D-1 = clinically sound day, D+1 = day after injection, D+5 = 5 d after injection, and D+7 = 7 d after injection.

DISCUSSION

These experiments established a protocol for inducing a transient clinical lameness in sows by amphotericin B injection into the distal interphalangeal joint. This lameness in sows was distinguishable from their preinjection gait by the subjective lameness score, GaitFour, and static force plate assessment. Lameness was no longer detected by static force plate or by subjective lameness scores by 7 d postinjection. The ability to induce lameness allows sows to be used as their own control and provides a population of known status to study lameness detection methods and devices. Data collection on the same sow when both sound and lame increase the study power by reducing within-animal variation and allow for a reduction in total sample size required for significance.

Amphotericin B was injected using 10 and 15 mg/mL concentrations. The 2 concentrations included in Exp. 2 were chosen arbitrarily because previous work suggesting an effective dose was lacking in the scientific literature. The results of these experiments suggest the 10 mg/mL concentration was sufficient to induce a repeatable transient lameness in sows. The investigators regarded the lowest dose that induced repeatable lameness to be preferable, and the 15 mg/mL concentration was not evaluated further. A 10 mg/mL concentration may represent the maximum concentration for repeatability because the amphotericin B tended to precipitate out of suspension at the 15mg/mL concentration. Using this concentration would make it difficult to consistently deliver the same quantity of the active substance at each distal interphalangeal joint.

Experiment 4 revealed a decrease in sensor activation as well as weight shifting to the nonlame foot and demonstrated a decrease in maximum pressure and stance time on the injected foot. Because of the inability to isolate claws individually, the GaitFour may not be a suitable tool to distinguish asymmetrical claw effects on the same foot but does demonstrate accurate lameness detection when both claws are injected or when determining clinical lameness that involves the entire foot or leg in a field setting that cannot be localized to a specific point. Experiment 4 showed that the GaitFour detected gait changes on all sows when lame was induced, and these gait changes resolved when the clinical lameness resolved.

The static force plate revealed a decrease in weight (kg) placed on the injected foot regardless of which foot was injected. Previous work by Knauer et al. (2007) revealed hoof lesions as the most prevalent lesion present in Midwestern cull sows. In this study, the experimental design did not measure an association between hoof lesions and clinical lameness. A repeatable lameness model would be useful for validating objective devices for detection of lame animals, benefiting farmers managing breeding herd sows.

Lame sows are often euthanized on farm, contributing to increased breeding herd mortality rates. Kirk et al. (2005) reported that over 70% of breeding herd sows with mobility problems are euthanized. Current lameness evaluation methods are subjective and biased by the observer (Crawford et al., 1991; Zinpro, 2011). To assist swine producers and veterinarians with lameness prevention and treatment, validated objective tools to detect sow lameness are needed. A consistent sow lameness model was developed in this series of studies, and new objective lameness tools were used and significant differences were observed. The ability to evaluate the same individual animal, both as sound and lame, controls for a wide range of specific gait variations, conformational differences, influence of BW, and hoof structure variables. The transient lameness duration is particularly important if the model is to have value for future pharmacologic assessment of analgesic molecules (USDA, 2008). Breeding herd lameness is a significant animal welfare and economical issue in the United States and worldwide. The induced sow lameness model outlined in the present studies is useful to gain a better understanding of clinical breeding herd lameness. The sow lameness model and objective tools can be applied to future pharmacological pain mitigation studies. In addition, future work could involve validating the objective lameness detection tools in the field.

LITERATURE CITED

Anil, S., L. Anil, and J. Deen. 2009. Effect of lameness on sow longevity. J. Am. Vet. Med. Assoc. 6:734–738.

Bowman, K. F., R. C. Purohit, V. K. Ganjam, R. D. Pechman, and J. T. Vaughan. 1983. Thermographic evaluation of corticosteroid efficacy in Amphotericin B-induced arthritis in ponies. Am. J. Vet. Res. 44:51–56.

Crawford, W. H., J. C. Houge, D. T. Neirby, A. Di Mino, and A. A. Di Mino. 1991. Pulsed radio frequency therapy of experimentally induced arthritis in ponies. Can. J. Vet. Res. 55:76–85.

Elmore, M., J. Garner, A. Johnson, B. Richert, and E. Pajor. 2010. A flooring comparison: The impact of rubber mats on the health, behavior, and welfare of group-housed sows at breeding. Appl. Anim. Behav. Sci. 123:7–15.

Engblom, L., N. Lundeheim, E. Standberg, M. Schenider, A. M. Dalin, and K. Andersson. 2008. Factors affecting length of productive life in Swedish commercial sows. J. Anim. Sci. 86:432–441.

Federation of Animal Science Society. 1999. Guide for the care and use of agricultural animals in agricultural research and teaching. 1st rev. ed. Fed. Anim. Sci. Soc., Savoy, IL.

Kirk, R. K., B. Svensmark, L. P. Ellegaard, and H. E. Jensen. 2005. Locomotive disorders associated with sow mortality in Danish pig herds. J. Vet. Med. Assoc. 52:423–428.

Knauer, M., K. J. Stalder, L. Karriker, T. J. Baas, C. Johnson, T. Serenius, L. Layman, and J. D. McKean. 2007. A descriptive survey of lesions from cull sows harvested at two Midwestern U.S. facilities. Prev. Vet. Med. 82:198–212.

Kotschwar, L., J. Coetzee, D. Anderson, R. Gehring, B. Kukanich, and M. Apley. 2009. Analgesic efficacy of sodium salicylate in an amphotericin B-induced bovine synovitis- arthritis model. J. Dairy Sci. 92:3731–3743.

Schenk, E., J. Merchant-Forde, and D. Lay. 2010. Sow lameness and longevity. USDA-ARS-MWA Livestock Behavior Research Unit, Purdue University, West Lafayette, IN.

Schulz, K., D. Anderson, J. Coetzee, B. White, and M. Miesner. 2011. Effect of flunixin meglumine on the amelioration of lameness in dairy steers with amphotericin B- induced transient synovitis-arthritis. Am. J. Vet. Res. 72:1431–1438.

Stalder, K. J., M. Knauer, T. J. Baas, M. F. Rothschild, and J. W. Mabry. 2004. Sow longevity. Pig News Inf. 25:53N–74N.

Sun, G., R. F. Fitzgerald, K. J. Stalder, L. A. Karriker, A. K. Johnson, and S. J. Hoff. 2011. Development of an embedded microcomputer-based force plate system for measuring sow weight distribution and detection of lameness. Appl. Eng. Agric. 27:475–482.

USDA. 2008. FDA Guidance Doc. 123. www.fda.gov/cvm/Guidance/guide123.htm. (Accessed 17 December 2008.)

Zinpro. 2011. Feet first swine locomotion scoring system. http://www.zinpro.com/lameness/swine/locomotion-scoring. (Accessed 3 October 2011.)