Detection of Lameness in Swine

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Detection of Lameness in Swine

Abstract
Sow lameness is a significant welfare issue and has major economic impacts for the U.S. swine industry. Lameness associated with painful joints and hock lesions is a common problem among sows housed in confinement; in addition, lameness has been ranked as the number-three reason for culling sows, comprising approximately 15 percent of the cull market in the United States. Furthermore, leg soundness was identified as the most common involuntary reason for culling sows. Sow lameness has been associated with several variables that result in poor performance, including decrease in litter size, poor farrowing performance, and decrease in sow longevity. Johnson and colleagues in 1997 reported that pro-inflammatory cytokines stimulated by lameness may inhibit growth, reduce appetite, and affect metabolism. If left untreated, lameness, inflammation, and pain negatively impact not only sow health and welfare but also the economic sustainability of producers. The high prevalence of lameness and lack of label-approved drugs for pain management places detection, treatment, and prevention of lameness as a major priority for the swine industry.

Lameness is defined by Merriam-Webster as "having a body part and especially a limb so disabled as to impair freedom of movement" or as "impaired movement or deviation from normal gait." Lameness not only becomes an issue to locomotor deficits but also deals with pain experienced by the animal. Detecting lameness on-farm at an early enough stage before swine become non-weight-bearing is an essential but difficult task to perform as the veterinarian or farmer. The following are both subjective and objective techniques that were evaluated during multiple trials conducted at the Swine Intensive Studies Lab (SISL) at Iowa State University.

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

Comments

Authors

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Introduction

Sow lameness is a significant welfare issue and has major economic impacts for the U.S. swine industry. Lameness associated with painful joints and hock lesions is a common problem among sows housed in confinement; in addition, lameness has been ranked as the number-three reason for culling sows, comprising approximately 15 percent of the cull market in the United States. Furthermore, leg soundness was identified as the most common involuntary reason for culling sows. Sow lameness has been associated with several variables that result in poor performance, including decrease in litter size, poor farrowing performance, and decrease in sow longevity. Johnson and colleagues in 1997 reported that pro-inflammatory cytokines stimulated by lameness may inhibit growth, reduce appetite, and affect metabolism. If left untreated, lameness, inflammation, and pain negatively impact not only sow health and welfare but also the economic sustainability of producers. The high prevalence of lameness and lack of label-approved drugs for pain management places detection, treatment, and prevention of lameness as a major priority for the swine industry.

Lameness is defined by Merriam-Webster as “having a body part and especially a limb so disabled as to impair freedom of movement” or as “impairing movement or deviation from normal gait.” Lameness not only becomes an issue due to locomotor deficits but also deals with pain experienced by the animal. Detecting lameness on-farm at an early enough stage before swine become non-weight-bearing is an essential but difficult task to perform as the veterinarian or farmer. The following are both subjective and objective techniques that were evaluated during multiple trials conducted at the Swine Intensive Studies Lab (SISL) at Iowa State University.
Materials and Methods

Subjective Tools to Assess Lameness

Pain-related behavior can be used as a tool to evaluate the presence and severity of pain indirectly, and when conducted appropriately, limits influence on the animal’s behavior or reaction by the manipulation of the observer. Behavioral parameters for on-farm live assessment focus on evaluating the following behaviors: body posture, activity, eating behavior, abnormal gait or movement, social interaction, physiological parameters (heart rate, respiratory rate, dilated pupils, hypertension, increased serum cortisol, and epinephrine), and/or vocalization.8

Lameness scoring systems are designed to categorize the degree of lameness demonstrated during locomotion and have been implemented so that caretakers can quickly and affordably quantify the prevalence of lameness in the herd on any particular day. Lameness scores typically are based on gait abnormalities during movement and deviations from normal posture while standing.9 Ideally, lameness scoring systems are practical, reliable, and consume little time.10 There are two main subjective scoring systems used in assessing lameness of livestock: visual analog scores (VAS) and numerical rating scores (NRS).

VAS was first utilized to quantify appetite sensations and pain sensation in human subjects.11,12 A VAS is composed of either a 100 mm or 150 mm line that is defined by two extreme definitions of sensation located at the line endpoints (e.g., extremely painful sensation or no sensation at all). Subjects will then place a mark on the area of the line that corresponds to their perception of the severity of that sensation. The sensation is then quantified by evaluating its distance from both ends of the line. Although VAS can detect more subtle clinical changes in animals,13 an absence of consensus regarding the optimal length of the line and the subjectivity among observers makes VAS a more difficult system to implement on-farm.14

The alternative, NRS systems, have been designed for many species to evaluate lameness6 and although the NRS system does not detect delicate changes in sensation as a VAS system would, it includes broad groups or scores with descriptive scales and definitions that apply varying clinical signs of pain and/or lameness. A four-point NRS scale [sound (0), mildly lame (1), moderately lame (2), and severely lame (3)] developed by Zinpro has been used in swine herds as a tool to quantify and evaluate lameness prevalence on a herd level.

Objective Tools to Assess Lameness

Pressure algometry (Figure 1) is a noninvasive tool used to determine sensitivity to pressure and indicate pain threshold of a subject. Pressure from the algometer is gradually increased over time with a constant rate of force on an area of interest until a withdrawal response is seen. Iowa State University has implemented a handheld pressure algometer (Wagner Force Ten™ FDX 50 Compact Digital Force Gage, Wagner Instruments, Connecticut, USA) with a 1 cm² flat rubber tip to measure mechanical nociceptive thresholds (MNTs) in kilograms of force (kgf). Pressure is applied perpendicularly to three landmarks [Cannon (C), Inner Claw (I), and Outer Claw (O)] on the affected limb in triplicate, immediately followed by the same landmarks tested in triplicate on the nonaffected limb. When a foot-lift response is observed, pressure is immediately removed, and the peak pressure representing the MNT is recorded.

The micro-embedded static force plate (Static force plate) was developed at Iowa State University to objectively identify varying severities of lameness among sows. This force plate was developed to be sensitive enough to recognize lameness undetectable to the subjective eye. The force plate was designed with a total dimension of 1,524 × 565 × 106 mm (length × width × height) and with 6.4-mm-thick aluminum plating comprising the top and bottom plate.15 A semiflexible epoxy (FlexCoat Vanberg Specialized Coatings, Lenexa, Kansas, USA) was mixed with sand to mimic the floor type that a sow would stand on daily (Figure 2). Sows are walked into a standard gestation stall with the flooring replaced by the Static force plate and remain in the stall for
15 minutes. During this time, each foot is measured independently, and the Static force plate is able to detect weight shifting activities with the sow standing.

To assess the gait of sows, a GaitRite (CIR Systems, Inc., Havertown, Pennsylvania, USA) pressure mat can be utilized to measure maximum pressure, stride length, stance time, number of sensors activated, and stride time per foot while walking (Figure 3). The pressure mat can be installed on a level floor surface in a facility and can be synchronized with a video recording of the sow's walk. This tool specifically evaluates changes in gait and detects abnormality in temporal rhythm. Each sow walks across the pressure mat repeatedly until three passes without stopping or running are recorded and all four feet register multiple times in the GaitFour software. Footfalls are individually highlighted, identified, sorted by time of initial footfall on the pressure mat, and saved as a completed walk.

Figure 1. Pressure algometer. Photo courtesy of http://www.wagnerinstruments.com/force_gauges/fdx_digital_force_gauge.php.

Figure 2. Static force plate. The bar, located down the middle of the Static force plate, helps to ensure that each hoof is measured individually. A camera allows the researcher to validate the placement of each sow hoof on each quadrant. Each sow receives feed placed in the trough to keep the sows still while data is being collected.

Figure 3. The GaitRite pressure mat (4.3 m with 13,824 sensors) floor-installed portable walkway system. The system enables measurements of vertical foot pressure, stride length, and stance time in a walking animal along a closed loop for sows to travel back and forth.
**Experimental Design**

Four trials were conducted at Iowa State University's SISL to validate the development of a transient, chemically induced lameness model in sows using physiological and mechanical measurements. The SISL was developed in 2008 at ISU's College of Veterinary Medicine as a premiere research laboratory for evidence-based improvement of swine performance, health, and well-being. The mission of the SISL is to "develop scientifically based solutions to a variety of challenges utilizing a comprehensive approach integrating health, performance, and well-being with a multidisciplinary team of [scientists]." For more information on the SISL, please access the website at http://vetmed.iastate.edu/research/labs/SwineLab.

Commercial cull sows with no signs of lameness were selected by the principal investigator and veterinarian on trial. This was determined by clinical evaluation of all four feet of the sow, assessing sows for signs of lameness while walking, and confirming that cull reasons were not due to lameness. Sows were snared and chemically anesthetized using the following anesthetic combination administered intramuscularly: Xylazine (4.4 mg/kg) (Anased®, Lloyd Laboratories, Shenandoah, Iowa, USA), Ketamine HCl (2.2 mg/kg) (Ketaset®, Wyeth, Madison, New Jersey, USA), and Telazamine HCl and Zolazepam HCl (4.4 mg/kg) used in combination (Telazol®, Wyeth, Madison, New Jersey, USA). During anesthesia onset, the entire claw was washed with mild soap and water to remove obvious fecal contamination. Following this wash, the treated foot was scrubbed for 5 minutes with iodine-based surgical solution (Operand®, Aplicare, Inc., Branford, Connecticut, USA) using 4 × 4 sterile gauze pads. The foot was then rinsed with 70 percent isopropyl alcohol until no surgical scrub remained. Approximately 20 minutes after anesthesia onset, sows were positioned in lateral recumbency, and an appropriate dose of amphotericin B in a 1 ml total volume was injected into the intraarticular space of the distal interphalangeal joint. Sows were evaluated using both subjective and objective tools to detect lameness the day before lameness induction (Day -1), the day after lameness induction (Day +1), and the last day of the study (Day +6). This protocol was used for trials 2–5 (Table 1).

<table>
<thead>
<tr>
<th>Trial</th>
<th>Number of Animals</th>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>9 finisher pig feet 10 multiparous sow feet</td>
<td><strong>Treatment 1:</strong> Four sows injected with high-dose amphotericin B.</td>
</tr>
<tr>
<td>II</td>
<td>4 anesthetized sows</td>
<td><strong>Treatment 1:</strong> Two sows injected with 1 ml sterile saline (control group). Sow 1 injected in left rear distal interphalangeal joint, and sow 2 injected in right rear distal interphalangeal joint. <strong>Treatment 2:</strong> Two sows injected with low-dose amphotericin B. Sow 3 injected in left rear distal interphalangeal joint, and sow 4 injected in right rear distal interphalangeal joint. <strong>Treatment 3:</strong> Two sows injected with high-dose amphotericin B. Sow 5 injected in left rear distal interphalangeal joint, and sow 6 injected in right rear distal interphalangeal joint.</td>
</tr>
<tr>
<td>III</td>
<td>6 anesthetized sows</td>
<td><strong>Treatment 1:</strong> Two sows injected with 1 ml sterile saline (control group). Sow 1 injected in left rear distal interphalangeal joint, and sow 2 injected in right rear distal interphalangeal joint. <strong>Treatment 2:</strong> Two sows injected with low-dose amphotericin B. Sow 3 injected in left rear distal interphalangeal joint, and sow 4 injected in right rear distal interphalangeal joint. <strong>Treatment 3:</strong> Two sows injected with high-dose amphotericin B. Sow 5 injected in left rear distal interphalangeal joint, and sow 6 injected in right rear distal interphalangeal joint.</td>
</tr>
<tr>
<td>IV</td>
<td>36 anesthetized sows</td>
<td><strong>Treatment 1:</strong> 24 sows injected with low-dose amphotericin B into the distal interphalangeal joint of one of four injection sites [left front claws (LF), right front claws (RF), left rear claws (LR), and right rear claws (RR)]. <strong>Treatment 2:</strong> 12 sows injected with low-dose amphotericin B injected into the distal interphalangeal joint of the right rear or left rear claws.</td>
</tr>
<tr>
<td>Pressure Algometry Trial</td>
<td>12 anesthetized sows</td>
<td><strong>Treatment 1:</strong> 12 sows injected with low-dose amphotericin B injected into the distal interphalangeal joint of the right rear or left rear claws.</td>
</tr>
</tbody>
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Objectives

I Trial 1: Determine appropriate injection technique of amphotericin B for intraarticular injection.

I Trial 2: Induce lameness in sows via intraarticular injection of amphotericin B.

I Trial 3: Assess cortisol levels, lameness scoring, and footfall parameters of amphotericin B-induced lame sows.

I Trial 4: Validate GaitRite and Static force plate as objective assessment tools for sow lameness.

I Trial 5: Evaluate the efficacy of pressure algometry as a tool to detect pain in sows induced lame.

Results

Trial 1
Feet collected from finisher pigs were not appropriate for technique practice due to dye flow back and inconsistent deposition of fluid into the distal interphalangeal joint space, regardless of needle gauge or fluid volume. There was no further work completed on this size of foot (data not presented). Using feet collected from multiparity commercial cull sows, 22 mm 23 gauge needles with 1 ml fluid volume resulted in the most accurate injection without dye flow back through the injection track. All frozen sagittal sections confirmed dye placement in the distal interphalangeal joint and confirmed proper technique of joint injection.

Trial 2
Production of chemically induced, transient lameness was accomplished in four anesthetized sows injected with amphotericin B and meat branding dye in the left rear medial distal interphalangeal joint. At the start of the experiment, all sows received a lameness score of 0 using the Zinpro NRS system. At 24h post-injection, 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. Inter-observer reliability of this four-point NRS scale also was evaluated. Seventeen observers reviewed Zinpro educational materials and evaluated 12 lame sows. The inter-observer reliability of locomotion scores for individual sows was high, with an average of 71 percent and a range of 53–94 percent.16

Trial 3
Lameness scoring analysis: At the start of the experiment, all sows received a lameness score of 0. All injections were administered successfully. The control sow group achieved a maximum average lameness score of 0.5 at 24h, which returned to 0 at 72h post-injection. Lameness scores for low-dose sows were greater compared to CO sows between 72 and 144h post-injection (p ≤ 0.019). The high-dose sow group scored greater (p = 0.019) lameness scores compared to control sows at 48h, and a trend was noted at 72h (p = 0.095). High-dose sows returned to baseline 48h earlier than the low-dose group.

Cortisol analysis: The low-dose sow group had a numerical increase in cortisol at 24h (p = 0.088) compared to control sows, and the high-dose group had an increase in cortisol at 48h (p = 0.014) compared to control sows. Control sows remained at or below baseline at 24, 48, and 216h post-injection. All treatment groups returned to levels less than 47 percent of their peak value at 216h post-injection for the six sows injected with amphotericin in either the left or right hind foot.

GaitRite analysis: When comparing Day -1 data of all four injected sows with post-treatment data, the total sensors activated by the injected foot decreased (p ≤ 0.05) at 48h post-injection and returned to baseline at 144h. The calculated pressure difference between the maximum pressure of the noninjected foot minus maximum pressure of the injected foot showed a pressure shift to the noninjected right foot when measured 48h post-injection (p ≤ 0.05). This shift in weight resolved by 144h post-injection.
Trial 4

**GaitRite analysis:** For the 24 sows that had one of four feet injected, there was a decrease \( (p \leq 0.05) \) in maximum pressure, stance time, and number of sensors activated for all three paired ratios \( (p \leq 0.05) \) when comparing data collected on Day -1 with Day +1. For the 12 sows that were injected in either the LR or RR, there was a decrease in stance time, maximum pressure, and number of sensors activated \( (p \leq 0.05) \).

**Static force plate analysis:** For the 24 sows that had one of four feet injected, injection of the LF, RF, and RR foot revealed a decrease in the weight being placed on the injected foot when comparing data collected on Day -1 with Day +1 \( (p \leq 0.05) \).

Trial 5

There was no significant difference in MNT between limbs on the day before lameness induction \( (p = 0.55) \), but there was a significant difference between sound and lame legs on the day after injection on all landmarks, with lame legs resulting in a lower MNT than sound legs \( (p = 0.002) \).

Discussion

This study established a protocol for induction of transient lameness in sows by injection of amphotericin B into the distal interphalangeal joint. This lameness in sows is distinguishable from their pretreatment gait by observational lameness score, cortisol levels, and GaitRite and Static force plate assessment. The ability to induce lameness allows sows to be used as their own control and provides a known population to study detection methods and devices. Collection of data on the same sow when both sound and lame will increase the study power by reducing inter-individual variation and decrease total sample size required for significance. Subjective and objective assessments are critical for on-farm detection, treatment, and prevention of lameness. It is essential that farms establish protocols to evaluate prevalence and severity of lameness using easy-to-learn hands-on techniques that can be implemented into the daily routine on the farm.

Subjective Assessments to Detect Lameness

Subjective assessments including NRS and pain behavior can be used to assess individual lameness as well as track changes of reduction or progression of lameness of the herd. The NRS system developed by Zinpro was found to be a beneficial tool for evaluating lameness and can be utilized on-farm for more reliable management decisions on lameness. By defining stages of lameness, managers can assess the prevalence and severity of lameness of the farm over time. NRS systems are easy to teach, and the high inter-observer reliability makes these systems dependable and an efficient approach for lameness detection.

Cortisol levels are a physiological parameter that can subjectively assess acute pain experienced by a sow. High levels of cortisol at 24 and 48h in Trial 3 indicate that cortisol can be used as a parameter to monitor pain induced by lameness but must be evaluated in tightly controlled circumstances, as cortisol is significantly influenced by a multitude of factors.\(^\text{17,18}\) However, it must be kept in mind that pain behavior is not specific to lameness and therefore pain-inducing diseases or conditions other than lameness cannot be ruled out. These behaviors can be used as indicators of painfulness when lameness has been diagnosed and can assist in detecting changes in the severity of individually lame animals.

Objective Assessment to Detect Lameness

Objective assessments also are powerful tools to be implemented on the farm, and although they require an initial investment, they provide objective evaluation of lameness without the bias of the observer. The Static force plate and pressure algometer are farm-friendly tools that can be implemented into already-established facilities and can benefit lameness evaluation of the farm greatly. The GaitRite pressure mat also is a validated tool to assess lameness but may not be functional for on-farm use at this time.
The Static force plate evaluated in Trial 4 detected a significant decrease in weight being placed when comparing sows when lame and sound, and this decrease was observed even when clinical signs of lameness were not evident. This data suggest that the force plate may be a tool that can detect lameness before lameness is detected by observation alone. The Static force plate is ready for on-farm use and is not only durable but can withstand years of wear and tear from sow hooves and harsh environments. This design also can be used with sows for extended periods of time and can be implemented during feeding time. This force plate is highly accurate, fits already existing equipment, and measures the weight of each hoof individually as well as the entire weight of the sow. A farm can easily track weight distribution of individual sows throughout their productive life and can help producers in implementing environmental or genetic programs to their breeding sow herds to decrease the occurrence of lameness.

The pressure algometer also is a tool that may soon be ready to use on-farm to detect lameness. Trial 5 concluded that pressure algometry is a valid objective assessment tool to evaluate pain-induced lameness in swine and can detect subtle changes and quantify severity of lameness as a means of kg of force. The pressure algometer is an easy-to-use tool that can be adapted for on-farm lameness evaluation and implemented into the daily routine.

The GaitRite successfully detected gait abnormalities and illustrated adaptations of the weight-bearing of sows between all four hooves. However, this tool has not yet been adapted for on-farm use due to its inability to survive the harsh climates of a confinement and the need for advanced software specifically implemented for swine. GaitRite pressure mats can play a role in future confinements and may be designed into alleyways to allow easy access to gait evaluation for the entire herd.

The multi-trial study described a transient, inducible model of lameness in sows. The ability to evaluate the same individual animal as both sound and lame controls for a wide range of specific gait variations, conformational differences, influence of body weight, and hoof structure variables. Validation of the GaitRite, Static force plate, NRS, and physiological parameters such as cortisol provide tools to evaluate potential lameness detection and measurement or treatment approaches for sows with a wide variety of naturally occurring field cases of lameness. Likewise, the transient duration of the lameness is particularly important if the model is to have value for future pharmacologic assessment of analgesic molecules. It allows for the individual animal to serve as its own biological control and to do this repetitively over multiple doses or routes of administration. This model may play a significant future role as a validated method of pain assessment to be used as a means of drug approval for pain relief in swine.

References


