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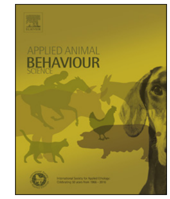

Characterization of the lying and rising sequence in lame and non-lame sows

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ABSTRACT

This study aimed to identify possible differences in the lying and standing sequence between lame and non-lame gestating sows. A total of 85 stall-housed sows (average parity 0.9 ± 1.14; range 0–4) were scored for walking lameness on a 3-point scale (1 = normal to 3 = severely lame) while moving to a separate gestation stall for recording of one lying-standing event on days 30, 60 and 90 of gestation. A video camera was positioned on the adjacent stall so sows' profiles were visible. Observations ceased when the sow laid-down and stood-up, or 2.5 h elapsed from recording commencement. From videos, postures and movements that occurred during lying-standing sequences were identified. Time (seconds) from kneeling to shoulder rotation (KSR), shoulder rotation to lying (SRHQ), total time to lie (TLIE); latency to lie (LATENCY; minutes) and number of attempts to successfully lie were recorded. Also, time taken from first leg fold to sit (TLS), time from sit to rise (TSR), and total time to rise (TRISE) were recorded. Sows were re-classified as non-lame (score 1) and lame (scores ≥ 2). Data were analyzed using mixed model methods with gestation day, and lameness as fixed effects and sow the random effect. On average, sows took 14.3 ± 1.39 s for KSR, 7.7 ± 0.79 s for SRHQ, 21.0 ± 1.37 s for TLIE and 63.6 ± 5.97 min for LATENCY. Furthermore, sows took 8.8 ± 2.80 s for TLS, 5.95 ± 1.73 s for TSR, and 10.3 ± 2.02 s for TRISE. There were no associations between lameness status or gestation day with time required for or the likelihood of performing the different movements of the lying and standing sequences ($P > 0.05$). Except for lame sows tending to sit more while transitioning from lying to standing than non-lame sows ($P = 0.09$). Seven different lying and 4 different standing combination deviation from the normal sequences, albeit each combination was infrequent and did not allow for statistical analysis. However, all together, deviations from the normal lying and standing sequence accounted for 22.7 % and 35 % of total observations; respectively. Under the conditions of this study, lameness did not influence the time taken or the likelihood of performing different movements and/or postures during normal lying-standing sequences. However, this could be due to lameness recorded here not being severe enough to affect the sequences. The observed deviations suggest that there is variation in the way sows lie and stand although more research is necessary to understand which factors contribute to such variation.

1. Introduction

The ability to express normal patterns of behavior, including lying and standing up without difficulty, is one of the 'Five Freedoms' proposed by the the Brambell Report (Brambell, 1965) to assess animal welfare. The sows' lying and standing behavior was first described by Baxter and Schwaller in 1983. The authors observed there was a high level of consistency in the way sows lie and stand allowing them to classify the lying and standing sequences. The lying sequence consists of 1) dropping to a kneeling position, 2) rotation of the upper body, and 3) lowering of the hindquarters, while the standing sequence consists of 1) rising up into a sitting position, and 2) lifting hindquarters to achieve standing position (Baxter and Schwaller, 1983). Baxter and Schwaller's (1983) classification of the lying and standing sequences has since been extensively used and referred to as the 'normal' sequences in later studies (e.g. Marchant and Broom, 1996; Harris and Gonyou, 1998; Boyle et al., 2002; Anil et al., 2002; Elmore et al., 2010; Calderón Díaz et al., 2014, 2015a; Calderón Díaz and Boyle, 2014). However, variation occurs and some sows may perform different movement combinations than those represented in the normal sequences (Calderón Díaz

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et al., 2015a). For example, Schmid and Hirt (1993) identified four different ways in which a sow lies down (i.e., ventral lying, lateral lying, falling on the side, and leaning on a wall), though they did not report similar information for the standing sequence. This suggests that there is a need for a more up-to-date depiction of the sow's lying down and standing up sequences since those presented by Baxter and Schwaller (1983).

Baxter and Schwaller (1983) suggested that movements of the normal lying and standing sequences are, to some extent, under the control of the sow and that they will continue once initiated. Additionally, they reported that time taken to complete any stage in the sequence is consistent between sows with a mean time of 3.1 s, 3.2 s and 4.8 s to perform each of the 3 movements (i.e. dropping to kneeling position; rotation of upper body and lowering hindquarters) of the lying sequence. They also reported sows need 1.5 s and 1.8 s to perform each of the 2 movements (i.e. rise up onto a sitting position and lifting hindquarters) of the standing sequence (Baxter and Schwaller, 1983). However, it seems that time required to perform each movement would vary according to several factors including housing system, genotype, and sow physiological state (Marchant and Broom;, 1996; Harris and Gonyou;, 1998). For example, gestating sows took 2 s, 1 s and 2 s for each lying movement (Marchant and Broom, 1996), while lactating sows took 1.5 s, 2.4 s and 5.4 s for each lying movement respectively (Harris and Gonyou, 1998). Space requirement could also impact time required to perform the lying sequence with sows with lower space allowance using less time to lie-down (Harris and Gonyou, 1998).

Another physiological aspect which can likely impact the lying and standing sequences is the sow's lameness status. Baxter and Schwaller (1983), suggested that lameness status would cause few problems, if any, to the normal lying and standing postural sequence when sows do not face space restriction. However, previous studies showed a negative association between lameness and some aspects of the lying and standing sequences in sows. For instance, Calderón Díaz et al. (2014), reported that lame sows had a shorter latency to lie down than non-lame sows. Roca et al. (2016), reported that sows transition quicker from standing to lying position when lame using a chemical synovitis model. Furthermore, Bonde et al. (2004), reported that severe lameness in lactating sows results in uncontrolled lying down behavior, increasing the risk of piglet death due to crushing (Blackshaw and Hagelsø, 1990; Damm et al., 2006) which is the major cause of piglet mortality (Marchant et al., 2000).

Lameness presents some challenges to the animal's ability to perform normal behaviour (Anil et al., 2009). Lame animals have posture alterations while walking and standing (e.g. shift their weight between limbs) which could reflect the discomfort they endure when they put their weight on an affected limb (Sprecher et al., 1997; Pastell and Kulula, 2007; Grégoire et al., 2013). These behavioural differences suggest that lame animals do not cope as successfully with their environment as non-lame ones. Thus, it is possible, that the time needed and the likelihood to perform the different movements of the normal lying and standing sequences is also affected by the sows' lameness status. Roca et al. (2016), reported that when sows are most lame, they would lie down using fewer postures, although such postures were not specifically described. Calderón Díaz et al. (2015b) conducted a qualitative pilot study to compare the movements during the lying down process in 10 gestating sows with different degrees of lameness. The authors did not observe any differences in the movements during the lying-down sequence of sows except for a severely lame sow that showed uncontrolled lying-down behavior and finished the lying-down sequence on a "dog sitting" position. The authors suggested that, indeed lameness score might not greatly affect the lying down sequence when space restriction is not an issue, as suggested by Baxter and Schwaller (1983), but the lying down sequence could be affected by a severe lameness status. To our knowledge, there are no other studies investigating the time used in each of the movements of the lying and/or standing sequences or the likelihood of performing each movement of the normal sequences in sows differing in lameness status.

This study aimed to identify possible differences in the lying and standing sequence between lame and non-lame gestating sows. We hypothesize that lameness status alters the sow's ability to control her movements and thereby impacts some aspects of the lying and standing sequences such as time required to perform, and the likelihood of performing each of the sequential movements. We predict that lame sows, due to their reduced locomotion ability, will use less time to complete a movement or not perform all movements in the lying sequence, as well as taking more time to complete the standing up sequence. We also hypothesize that as gestation progresses, and thus space required to lie and stand increases (Mumm et al., 2019), sows will perform the lying and standing sequence movements in less time as a result of the reduction in space allowance in the stall due to the increase in sows' dimensions during gestation (McGlone et al., 2004). Finally, we also aimed to pictorially depict the repertoire of movement combinations that sows performed during the lying and standing movements that varied from the normal sequences.

2. Materials and methods

2.1. Ethical statement

This study was approved by Iowa State University Institutional Animal Care and Use Committee # 6-15-8035-S, and it was conducted in accordance with the Guide for the Care and Use of Agricultural Animals in Research and Teaching as issued by the American Federation of Animal Science Societies (FASS, 2010). No invasive measures were used to during this study.

2.2. Experimental design and animal husbandry

This was an observational study whereby sows were managed as per usual practice on the farm. None of the authors had input in daily management of the sows and thus, farm staffs were in charge of performing overall health checks as per routine practice. This included pregnancy determination which would result in removal from study when negative. The study was conducted at the Lauren Christian Swine Research Center located on the Bilsland Memorial Swine Breeding Farm near, Madrid, IA from August 2015 to May 2016. Eighty-five females (average parity 0.9 ± 1.14; range 0–4) were included. Gilts used represented the entire population for the 10th generation of Yorkshire pigs divergently selected for Residual Feed Intake (RFI; n = 26 low RFI and n = 20 high RFI) at Iowa State University. The remaining 39 animals were cross-bred Yorkshire × Landrace multiparous sows. Hereafter, all animals included will be referred as sows. Sows were individually housed in gestation stalls (2.61 × 0.76 m) with fully slatted concrete flooring as per normal practice in the United States until moved to farrowing crates approximately four days prior to parturition. At approximately 30 d, 60 d and 90 d of gestation, sows were removed from their home gestation stall, walked down the alleyway for approximately 7.6 m and moved into another identical gestation stall where a video camera had been previous installed to record one lying and one standing event. The sow was allowed to walk at her own pace to assess lameness on the same days. Once the video recording was completed, the sow was returned to her home gestation stall.

The gestation barn was double curtain sided to allow for natural ventilation. Additional fans provide cooling in the summer months, and supplemental heat is provided in the winter. Sows were manually fed a gestation diet once daily that met or exceeded NRC requirements (NRC, 2012) and they were provided *ad libitum* access to water in troughs at the front of each gestation stall. From the 85 sows originally enrolled in the study, 24 sows were not pregnant and thus were immediately removed from the study once the animal was confirmed *open*. Another 4 sows were removed as they were diagnosed as Severe Combined Immuno-Deficiency (SCID) carriers and utilized at the Iowa State

Veterinary Laboratory for a separate study. Therefore, 85, 70 and 55 sows were video scored for lameness and video recorded on day 30, 60 and 90 of gestation, respectively.

2.2.1. Lameness

A 3-point scale system adapted from the scoring system developed by Main et al. (2000) was used to subjectively evaluate lameness. The scoring system includes behavior, standing posture and gait to classify animals into different lameness scores. Sows received a score of 1 = **non lame** (i.e. sow is bright, alert and responsive, sow stands squarely on all four legs and has even strides); 2 = **mildly lame** [i.e. sow is bright but less responsive (may remain lying or dog sitting before eventually rising), she is limping and has shortened stride]; or 3 = **severely lame** (i.e. sow is unwilling to leave familiar environment, she may not bear weight on affected limb and has shortened stride. If a sow received a lameness score of 2 or 3, the affected leg was recorded. To assess lameness, the observers opened the front gate of the sows' gestation stall and encouraged them to exit into the alleyway. At this point, the observers started to note sow behavior as per the scoring system. Once the sow exited their gestation stall, sows were allowed to walk back and forth in the alleyway connecting their home gestation stall and the testing gestation stall as required for stiffness to subside. Then while sows walked free of stiffness, their standing posture and gait were observed and a lameness score was assigned to each sow by two alternating trained observers (Kappa statistic = 0.79; indicating a substantial agreement beyond that expected by chance). A Kappa Statistic is often used to measure inter-observer reliability for categorical traits such as scores. Unlike percentage agreement, it considers the likelihood that the results could be due to chance. A score of 0 means the results were entirely due to chance and 1 is perfect agreement between two observations (McHugh, 2012). Kappa Statistics scores of 0.4 to 0.6 mean a moderate level of agreement, 0.61–0.8 a substantial agreement, and 0.81–0.99 almost perfect agreement (Viera et al., 2005). Only one sow was classified as having a lameness score 3 during the trial; thus, lameness was re-classified as non-lame (score = 1) and lame (score = ≥ 2). In total, 31 sows were classified as lame on day 30 of gestation, 39 sows were classified as lame on day 60 of gestation and 19 sows were classified as lame on day 90 of gestation. Ninety-eight-percent of lameness was observed in the rear legs.

2.2.2. Behavioral observations

At approximately 30, 60 and 90 d of gestation, sows' were individually recorded for one lying down and one standing up sequence. The sow profile was continually video recorded (GoPro Hero 4, GoPro Inc., San Mateo, CA, USA). The camera was positioned on the adjacent gestation stall (0.76 m from the sow), approximately 50 cm from the floor. The camera was set at 1080p, and 30FPS shutter speed. Sows were video recorded between 0800 and 1700. Video recording terminated once the sow had performed one lying and one standing sequence or once 2.5 h had elapsed since recording started. The number of sows' video recorded per day along with the number of sows performing one lying and one standing sequence is presented in Table 1. Videos were first converted from mp4 to AVI format using readily available software (http://www.dvdvideosoft.com/products/dvd/Free-MP4-Video-Converter.htm). From the video, postures and movements that occurred during the lying-standing sequences were identified.

Lying down was defined as three sequence movements that have been previously described by Baxter and Schwaller (1983) where "(i) the sow drops into a kneeling position, (ii) then the sow rotates the upper part of her body to bring a shoulder and side of the head to rest on to the floor and (iii) finally, the sow lowers her hindquarters and finishes in either ventral or lateral recumbency." Sows were classified as ***having attempted to** lie down* if either of the first two movements were observed. However, in some cases, sows were observed to begin the third movement in the sequence, but were unable to successfully slide one of their rear legs under the body, when this occurred they rapidly stood up again. In these cases, it was considered that lying had been attempted. Time from kneeling to shoulder rotation (KSR; s), time from shoulder rotation to lying (SRHQ; s), total time to lie down (TLIE; s), latency to lie down (LATENCY; min) and the number of attempts (ATTEMPTS) to successfully lie down and deviation occurrences were recorded. When a deviation occurred, the different movements performed were recorded and pictorially depicted. In total, eight different movement combinations were performed by sows during the lying sequence, of which seven were considered deviations (Fig. 1).

Standing up was classified according to the movement sequence described by Baxter (1984) whereby "(i) the sow positions her body onto her sternum with her front legs folded beneath her body and rises to a sitting position, (ii) then the sow starts to lift her hindquarters straight off the floor to achieve full standing position." ***Time*** (s) to stand was defined as the first leg fold to sit (TLS), time from sit to rise (TSR), and total time to rise (TRISE) were recorded. When a deviation from the normal standing sequence occurred, the different movements performed were recorded. In total, five different movement combinations (four of which were considered deviations) were performed by sows during the standing sequence (Fig. 2).

2.3. Statistical analysis

All analyses were carried out in SAS v9.4 (SAS Inst., Cary, NC). For all analyses, statistical differences were reported when $P < 0.05$ and statistical trends were reported when $P > 0.05$ and < 0.10. Predicted variables were evaluated for normality using the Shapiro-Wilk test and examining the normal plot. Each sow was considered the experimental unit. All variables were analyzed using mixed model equations methods with repeated measurement in PROC MIXED. Models included lameness, gestation day and their interaction as fixed effects. Sow was included as a random effect. Genetic line was confounded within parity and therefore was not used as a predictor variable in the models. Results are reported as least square means ± SE. The likelihood of kneeling, rotating shoulders, lying, folding legs, sitting, standing and deviations from the normal sequences were analyzed using binomial logistic regression in PROC GENMOD. The attempts to successfully lie down were classified as 1, 2 and 3+ and they were analyzed using multinomial logistic regression in PROC GENMOD. For all logistic regression analysis, models included gestation day and lameness as fixed

Table 1
Descriptive statistics in a study characterizing the lying-standing sequences in lame and non-lame Yorkshire and Yorkshire X Landrace sows.

Gestation day	No. sows video recorded[a]	No. of lame sows[b]	No. sows that laid down and stood up[c]	No. of lame sows that laid down and stood up[d]
30 d	85	49	64	26
60 d	69	39	53	30
90 d	52	20	42	16

[a] Sows that remained pregnant and were video recorded at day 30, 60 and 90 of gestation from the profile using a Go-Pro Hero 4 camera attached to the adjacent gestation stall.
[b] Sows that were classified as lame or non-lame on a 0 or 1 scale adapted from Main et al., 2000 from the total number video recorded per observation.
[c] Sows that performed the lying and standing behavior as defined by Baxter and Schwaller (1983) and Baxter (1984) at gestation day 30, 60 and 90.
[d] Lame sows that performed the lying and standing behavior at gestation day 30, 60 and 90.

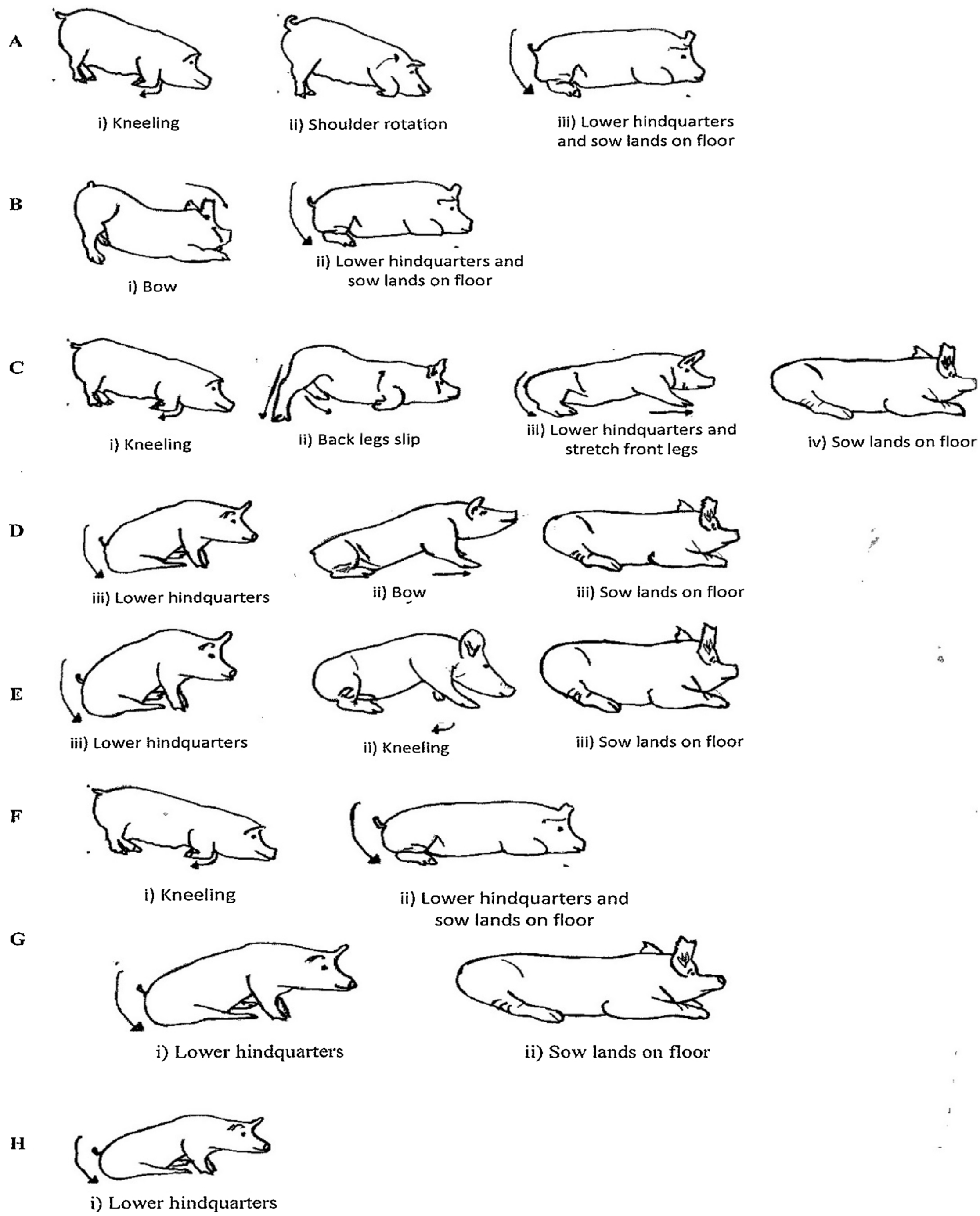

Fig. 1. Different movement combinations observed from filming the lying down sequence in breeding herd sows P1- P5 at the Lauren Christian Swine Research Center at Iowa State University Bilsland Memorial Swine Breeding Farm. A) Normal lying down sequence as described by Baxter and Schwaller (1983), B to H represent deviations from the normal lying down sequence.

effects, with sow included as the random effect. Results for logistic regression are reported as odds ratios (OR) with the associated 95 % confidence intervals (CI). There were few observations recorded for each of the movement combinations deviating from the normal lying and standing sequences and thus, statistical analysis was not possible. However, descriptive statistics (i.e. percentage of observation by lameness score) are presented in Figs. 3 and 4.

3. Results

Lying down sequence: On average, sows took 14.3 ± 1.39 s for KSR, 7.7 ± 0.79 s for SRHQ, 21.0 ± 1.37 s for TLIE and 63.6 ± 5.97 min for LATENCY. There was no interaction between lameness and gestation day ($P > 0.05$). Lameness was not a significant source of variation for any studied traits in the lying down sequence ($P > 0.05$). Gestation day was not associated the time taken to complete any of the movements during the lying sequence ($P > 0.05$; Table 2). There were no associations between lameness status, or gestation day and the likelihood of kneeling, shoulder rotation, lying or ATTEMPTS ($P > 0.05$). Additionally, there were no significant associations between lameness status, gestation day and the likelihood to perform a deviation from the normal lying sequence ($P > 0.05$). The percentage of observations for each movement combination to lie down for lame and non-lame sows is presented in Fig. 3. Sequences that deviated from the normal lying

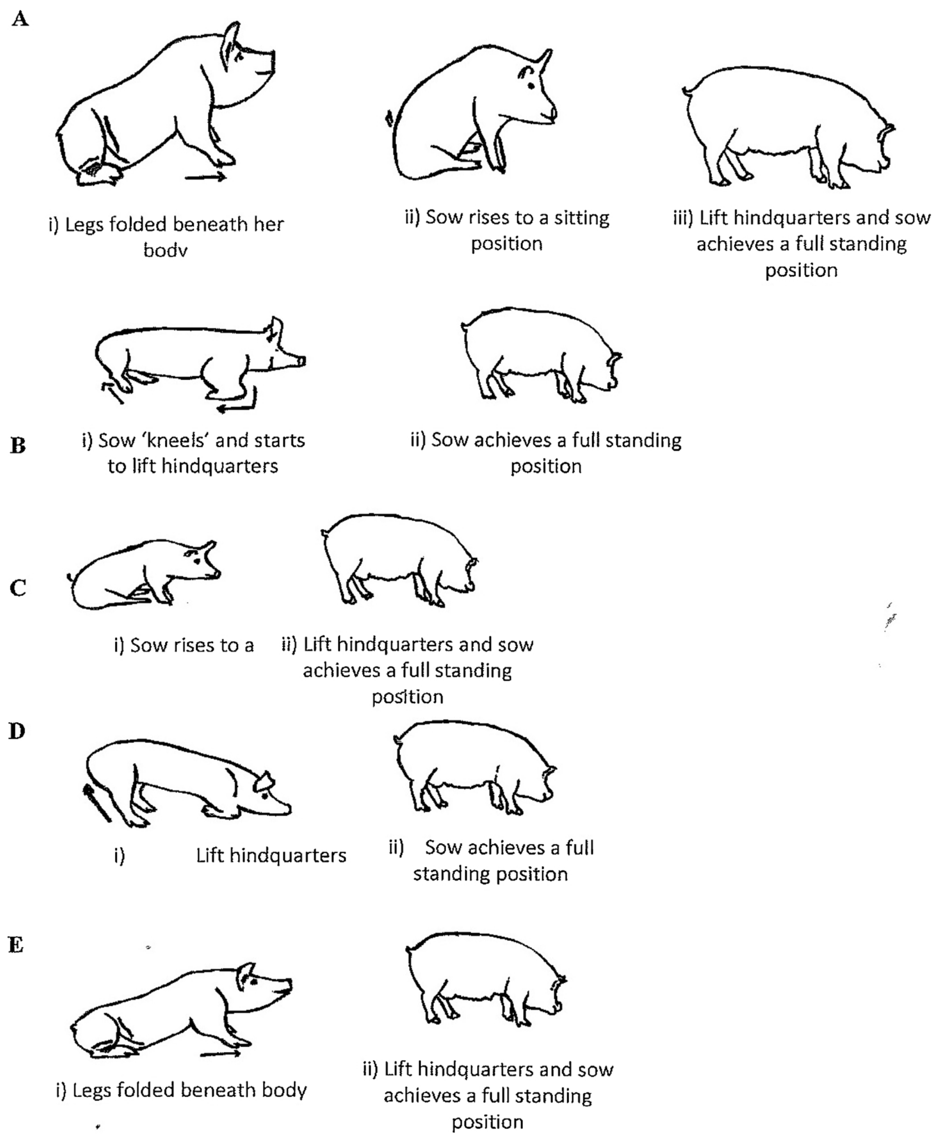

Fig. 2. Movement combinations observed from filming the standing sequence. in breeding herd sows P1- P5 at the Lauren Christian Swine Research Center at Iowa State University Bilsland Memorial Swine Breeding Farm. A) Normal standing up sequence as described by Baxter (1984)., B to E represent deviations from the normal standing up sequence.

down sequence accounted for 22.7 % of all observations. The most common deviations observed were sows only lowering hindquarters and thus finishing the observation in a sitting position [9.2 % of observations (9.5 % in non-lame and 9.0 % in lame sows observations); Fig. 1H]; sows kneeling and then lowering hindquarters without rotating their shoulders [8.0 % of observations (6.8 % in non-lame and 9.0 % in lame sows); Fig. 1F] and sows bowing and then lowering their hindquarters to land on the floor [2.5 % of observation (2.7 % in non-lame and 2.2 % in lame sows); Fig. 1B].

Standing up sequence: On average sows took 8.8 ± 2.80 s for TLS, 5.95 ± 1.73 s for TSR, and 10.3 ± 2.02 s for TRISE. There was no interaction between lameness and gestation day ($P >$ 0.05). Lameness or gestation day were not a significant source of the time taken to perform the different movements of the standing up sequence ($P >$ 0.05; Table 3). There were no significant associations between lameness status, and gestation day and the likelihood of performing different movements during the standing behavioral sequence ($P >$ 0.05). However, lame sows tended to be more likely to sit while transitioning from lying to standing when compared to non-lame sows (OR = 1.64; 95 % CI = 0.90–2.98; $P =$ 0.09). The percentage of observations for each movement combination to stand for lame and non-lame sows is presented in Fig. 4. Sequences that deviated from the normal standing up sequence accounted for 35.0 % of all observations. The most common deviations observed were sows folded their legs beneath their body and then achieved a full standing position [22.1 % of observations (16.5 % in non-lame and 27.0 % in lame sows observations); Fig. 2E]; sows rise to a sitting position and then achieved full standing position [8.6 % of observations (6.8 % in non-lame and 10.1 % in lame sows observations); Fig. 2C]; and sows kneeled and started to lift their hindquarters to achieve a full standing position [3.7 % of observations (2.7 % in non-lame and 4.5 % in lame sows observations); Fig. 2B]

4. Discussion

Contrary to our hypothesis, lameness status did not alter the time needed for, or the likelihood of performing the different movements of normal lying-standing sequences in gestating sows. Previous studies reported that lame sows lie down faster (Calderón Díaz et al., 2014) and use fewer postures (Roca et al., 2016) to transition from standing to lying; however such differences were not observed in the present study. It is possibly that differences are due to the lameness severity recorded in these studies. More than a third of sows in the study by Calderón Díaz

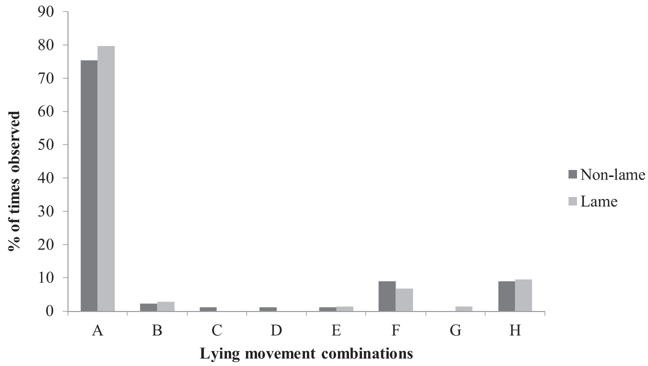

Fig. 3. Percentage of times eight different movement combinations were observed while filming the lying down sequence in non-lame and lame sows. A) Normal lying down sequence as described by Baxter and Schwaller (1983) where sow drops into a kneeling position; rotates shoulders and lowers hindquarters. B) Sow bows and then lowers hindquarters. C) Sow drops to a kneeling position; her back leg slips; then sow lowers hindquarters while stretching front legs. D) Sow lowers hindquarters; assumes a bowing position and then lands on floor. E) Sow lowers hindquarters; then drops to a kneeling position and then lands on floor. F) Sow drops to a kneeling position and then lowers hindquarters to land on the floor. G) Sow lowers hindquarters and lands on the floor. H) Sow lowers hindquarters and finishes in a sitting position.

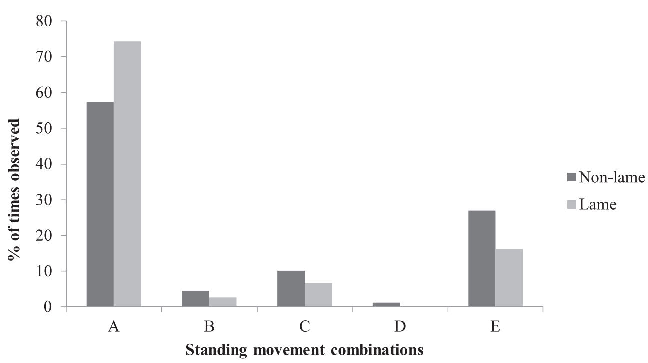

Fig. 4. Percentage of times five different movement combinations were observed while filming the standing up sequence in non-lame and lame sows. A) Normal standing up sequence as described by Baxter (1984) where sow folds her legs beneath her body; then rises to a sitting position to finally lift her hindquarters and achieve a full standing position. B) Sow "kneels" and starts to lift her hindquarters and then achieves a full standing position. C) Sow rises to a sitting position; then lifts her hindquarters and then achieves a full standing position. D) Sow lifts her hindquarters and then achieves a full standing position. E) Sow folds her legs beneath her body and then achieves as full standing position.

et al. (2014) were severely lame and the findings reported by Roca et al. (2016) were only observed on the day sows were most lame following lameness induction. In this study, there were no severely lame sows and thus, it is possible that lameness only affects the lying down behavior when it is severe. We expected that lame sows would take longer to complete the standing sequence; however, similar to the results of Roca et al. (2016); lameness status did not alter the standing sequence. Nonetheless, there was a tendency for lame sows to be more likely to sit while transitioning from lying to standing. It is possible that lame sows needed to adopt this position as they might feel discomfort when bearing weight on their affected limb and needed some kind of *break/rest* to be able to achieve full standing position.

In this study, several movement combinations that deviated from the normal lying and standing sequences were observed. Although each different movement combination was not observed very frequently, deviated sequences accounted for 22.7 % of observed lying down events and 35.0 % of standing up events suggesting that sows could have individual characteristics when it comes to performing certain behaviors (Baxter and Schwaller, 1983). Future studies should investigate the within sow repeatability of such sequences and which animal factors (e.g. limb, claw and body lesions, body weight, among others) could contribute to sows lying and/or standing using different movement combinations than those described in the normal sequences. The observed percentage of lying down movement combinations deviating from the normal sequences is higher than the one reported by Bonde et al. (2004) in lactating sows of 17.5 %, (this included abnormal, uncontrolled and interrupted lying behavior as well as slipping and stepping while lying down). Differences between studies could be due to timing when sows were observed (gestation in this study and lactation by Bonde et al., 2004) or to the methods used to observe the animals. In this study, videos were used which allowed us to do more detailed observations of the lying sequence and identify movements that could occur fairly quickly and that would not be easy to observed by the naked eye when performing direct observations. We were unable to find a similar study where different movement combinations deviating from the normal standing up sequences were recorded.

Space requirement could also impact time required to perform the lying sequence as sows with lower space allowance use less time to lie-down (Harris and Gonyou, 1998). As gestation progresses, dynamic space requirements to lie down and stand up increase (Mumm et al., 2019) while space allowance decreases inside the gestation stall as a result of changes in sow dimensions (McGlone et al., 2004). Thus, we hypothesized that as gestation progressed sows would lie down and stand up quicker. However, no differences were observed between gestation days for the time require for, or the likelihood of performing the different movements in both the lying and standing sequences. In this study, it was not possible to measure sow dimensions and therefore we do not know how much space allowance was reduced, if any, inside the gestation stall as gestation progressed. However, according to Rohde Parfet et al. (1989) differences as little as 5 cm in housing dimensions could impact sow behavior. Therefore, it is possible that space allowance was not reduced to a point where it impacted sow behavior, or the extra space required to perform the sequences as parity progress is below the threshold for impacting sow behavior. Indeed, increase in dynamic space requirements to lie and stand reported by Mumm et al. (2019) was only 0.13 m^2. Future studies should be carried out using gestation stalls of various dimensions and sow body dimensions should be recorded.

5. Conclusion

Under the conditions of this study, lameness status and gestation day were not associated with the time taken for or the likelihood of performing the different movements of the normal lying and standing sequences. All sows classified as lame only exhibited mild lameness and thus, it is possible that lameness recorded in this study was not severe enough to affect sow lying and standing behavior. Nonetheless, the tendency observed in lame sows for an increased likelihood to sit while transitioning from lying to standing suggest that lame sows need a rest to secure their position to achieve a full standing sequence. Future studies should include a wider range in lameness scores. The utilization of video recording for the lying and standing sequences offers a unique and novel look at each step in the process of lying and standing that goes beyond human observation capabilities. Although we could not carry out statistical analysis, we observed a high percentage of sows performing "abnormal" lying and standing sequences suggesting that individual sow characteristics be associated with sows performing certain behavior; however, this warrants future investigation.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

Table 2
Time to perform lying sequence[1] movement differences (LS means ± SE) between lame and non-lame multiparous Yorkshire and Yorkshire × Landrace sows at 30, 60 and 90 days of gestation.

	Time from Kneeling to shoulder rotation[1], s		Time from shoulder rotation to lower hindquarter[1], s		Total time to lie down[2], s		Latency to lie down[3], min	
Variables	LS means	± SEM	LS means	± SEM	LS means	± SEM	LS means	± SEM
Lameness[4]								
Non-lame	13.3[a]	± 1.35	7.7[a]	± 0.78	20.3[a]	± 1.27	68.7[a]	± 5.78
Lame	15.4[a]	± 1.44	7.7[a]	± 0.80	21.7[a]	± 1.48	58.5[a]	± 6.17
Gestation day[5](d)								
30	12.6[a]	± 1.48	8.0[a]	± 0.79	20.3[a]	± 1.45	70.9[a]	± 6.08
60	13.9[a]	± 1.56	7.4[a]	± 0.86	20.5[a]	± 1.70	65.5[a]	± 6.33
90	16.6[b]	± 1.74	7.7[a]	± 0.94	22.4[a]	± 1.75	53.5[a]	± 7.08

[a,b] Within each column, significant differences between levels of each predictor variable; $P < 0.05$.
[1] Lying was defined as three sequence movements that have been previously described by Baxter (1984) where "(i) the sow drops into a kneeling position, (ii) then the sow rotates the upper part of her body to bring a shoulder and side of the head to rest on to the floor and (iii) finally, the sow lowers her hindquarters and finishes in either ventral or lateral recumbency.".
[2] Time to complete the lying sequence from kneeling position to lowering the hindquarters and finishing in either ventral or lateral recumbency.
[3] Total time standing determined from observation begins until sow successfully lies down or 2.5 h.
[4] Lameness was classified as 0 (non-lame) or 1 (lame) on a scale adapted from Main et al. (2000).
[5] Observations were done at approximately 30, 60 and 90 days of gestation.

Table 3
Time to perform standing sequence[1] movement differences (LS means ± SE) between lame and non-lame multiparous Yorkshire and Yorkshire × Landrace at days 30, 60 and 90 of gestation.

	Time from leg-fold to sit[1], s		Time from sitting to rise up[1], s		Total time to rise up[2], s	
Variables	LS means	± SEM	LS means	± SEM	LS means	± SEM
Lameness[3]						
Non-lame	11.6[a]	± 3.10	4.8[a]	± 1.92	9.3[a]	± 1.98
Lame	6.0[a]	± 2.50	7.1[a]	± 1.54	11.4[a]	± 2.06
Gestation day[4] (d)						
30	7.0[a]	± 2.62	8.7[a]	± 1.64	11.7[a]	± 2.11
60	13.7[a]	± 2.82	5.5[a]	± 1.83	11.8[a]	± 2.29
90	5.7[a]	± 3.77	5.8[a]	± 2.29	7.5[a]	± 2.61

[a,b]Within each column, significant differences between levels of each predictor variable; $P < 0.05$.
[1] Standing up was classified according to the sequence of movements described by Baxter (1984) whereby "(i) the sow positions her body onto her sternum with her front legs folded beneath her body and rises to a sitting position, (ii) then the sow starts to lift her hindquarters straight off the floor to achieve full standing position.".
[2] Time to complete the standing up sequence from folding her legs beneath her body position to lifting hindquarters and achieving a full standing position.
[3] Lameness was classified as 0 (non-lame) or 1 (lame) on a scale adapted from Main et al. (2000).
[4] Observations were done at approximately 30, 60 and 90 days of gestation.

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