

Effects of gestation housing system and floor type during lactation on locomotory ability; body, limb, and claw lesions; and lying-down behavior of lactating sows¹

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ABSTRACT: This study evaluated the influence of housing system during gestation and floor type during lactation on the welfare and lying-down behavior of lactating sows. Multiparous sows ($n = 85$) were housed either in individual gestation stalls ($n = 42$) or loose ($n = 43$) in a single dynamic group with 2 electronic sow feeders moved to farrowing crates on either slatted steel ($n = 48$) or cast iron ($n = 37$) flooring. Lameness (0 = normal to 5 = severely lame) was scored on transfer to the farrowing crate (−5 d). Limb and body lesions were recorded on −5 d, 24 h after entering the farrowing crate (−4 d), 10-d postpartum, and before weaning. Claw lesions were recorded on −5 d and before weaning, whereas all behavioral observations were made on −5, −4, and 10 d. Median (M_e) scores were calculated for claw, body, and limb lesions and classified as either less than or equal to the M_e or greater than the M_e lesion scores. Sows were classified as nonlame (≤ 1) or lame (≥ 2). Loose-housed sows had an increased ($P < 0.01$) risk of lameness; a reduced ($P < 0.05$) risk for claw lesions, particularly white line damage, horizontal wall

cracks, and dewclaw injuries; and a reduced ($P < 0.05$) risk for calluses and bursitis on the limbs compared to stall-housed sows. Sows housed on cast iron floors during lactation had a reduced ($P < 0.01$) risk for heel overgrowth and erosion and heel-sole cracks compared with sows on slatted steel floors. There was no ($P > 0.05$) association between flooring type during lactation and body lesion score. On −4 d, loose-housed sows had a shorter latency to lie down ($P < 0.01$), spent more time inactive ($P < 0.05$), and shifted weight between the limbs more often ($P = 0.05$) while standing compared with stall-housed sows. Lame sows had a shorter ($P < 0.01$) latency to lie down compared to nonlame sows on −5 and −4 d. In conclusion, there was an increased risk of lameness in sows housed loose compared to those housed in gestation stalls on transfer to the farrowing crate. Claw health deteriorated in the farrowing crate regardless of gestation housing or floor type but the deterioration in claw health was increased on slatted steel compared to on cast iron.

Key words: flooring type, gestation housing system, lameness, lying-down behavior, sows, welfare

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INTRODUCTION

Gestation stalls were banned in the European Union in January 2013. Although loose housing offers more freedom of movement and space, studies indicate

that aggression and injury can be serious problems in these systems (Broom et al., 1995; Anil et al., 2003). These issues contribute to the problem of claw lesions (Spoolder et al., 2009) and lameness in loose-housed sows (Kroneman et al., 1993b). Even though Dewey et al. (1993) estimated that between 5% and 20% of lameness in sows is caused by claw lesions, findings from recent work that has attempted to relate claw lesions to lameness are contradictory. Anil et al. (2007), KilBride et al. (2010), and Pluym et al. (2011) reported that lameness was related to white line damage; erosion at the toe, sole, or heel; and dewclaw length, re-

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spectively, whereas Grégoire et al. (2013) found no relationship between claw lesions and lameness.

Despite concerns about the welfare of sows in farrowing crates, their use will likely continue for the foreseeable future (Weng et al., 2009). Given the impact that flooring in farrowing crates can have on sow behavior and welfare (Boyle et al., 2000a), it is worthy to explore the interaction between gestation housing system and farrowing crate floor type. Therefore, the aims of this study were to 1) determine the effect of housing system during gestation on locomotory ability of sows before farrowing; 2) study the effect of housing system during gestation and floor type during lactation on body, limb, and claw lesions, as well as lying-down behavior; and 3) investigate the relationship between lameness and lying-down behavior.

MATERIALS AND METHODS

Care and Use of Sows

The farm on which this experimental work was conducted was in compliance with Statutory Instrument S.I. No. 311 of 2010 European Communities (Welfare of Farmed Animals) Regulations 2000. No invasive measures were used, so the experiment did not require licensing under the European Communities (amendment of Cruelty to Animals Act of 1876) Regulations 2002.

The study was conducted on the experimental farm of the Pig Development Department, Teagasc Animal and Grassland Research and Innovation Centre (Moorepark, Fermoy, Co., Cork, Ireland), from December 2010 to June 2011. A total of 85 Large White × Landrace multiparous sows were included in the experiment, which commenced on the day that the sows were transferred from the gestation to the farrowing accommodations.

During gestation, 42 sows (average parity 3.2 ± 0.99 ; average BW 260.2 ± 40.06 kg) were housed in individual gestation stalls (2.13×0.62 m) with fully slatted concrete flooring, and 43 sows were loose-housed (average parity 3.3 ± 0.94 ; average BW 267.5 ± 28.80 kg) as a single dynamic group in a 29.9×10 m pen equipped with 2 centrally positioned electronic sow feeders. The loose house had 20 resting areas (2.09×2.58 m) with solid concrete floors. Each resting area was divided by a 1.11-m-high concrete wall. Additionally, the loose house had a central, fully slatted area (29.9×4.85 m) that could be used for exercise and dunging. Group size varied from 30 to 70 sows throughout the experiment, and the available space was maintained at a minimum of 4.3 m²/sow. On d 110 of gestation, the sows BW, BCS, and back-fat thickness were recorded before transfer to farrowing crates. “Batch farrowing” was followed on the experimental farm such that batches of sows coming

from either housing system were transferred to the farrowing facilities every 3 wk.

Farrowing facilities consisted of 8 mechanically ventilated, thermostatically controlled rooms, each containing 10 farrowing pens. Each farrowing room was used consecutively as it became available. Room temperature was maintained at 20°C before farrowing, increased to 24°C for the first 2wk of lactation, and subsequently lowered to 20°C. Pens (2.3×1.65 m) with fully slatted floors were fitted with a centrally positioned, 2.3×0.5 m farrowing crate. Heating pads (1.51×0.40 m) for piglets were located on either side of the farrowing crate and maintained at 36°C. The first 48 sows (25 loose-housed and 23 stall-housed sows; average parity 3.2 ± 1.06 ; average BW 268.3 ± 34.34 kg) in the study were housed on a slatted steel floor (Nooyen Pig Flooring, Deurne, the Netherlands) in the farrowing house. However, the slatted steel floor in the 8 farrowing rooms was gradually replaced such that the remaining 37 sows (18 loose-housed and 19 stall-housed sows; average parity 3.3 ± 0.84 ; average BW 258.2 ± 35.02) were housed on cast iron floors (Nooyen Pig Flooring, Deurne, the Netherlands) in the farrowing house. Daytime lighting (0830 to 1700 h) was provided by manually controlled overhead fluorescent strips (40 lux), and, if needed, nighttime lighting was provided by energy-saving bulbs (3 lux).

Throughout gestation, sows were fed, on average, 2.3 kg/day of a 3.5:1 (water:meal) wet diet that provided 13.1 MJ DE/kg, whereas, during lactation, sows had ad libitum access to a 4.5:1 (water:meal) wet diet formulated to provide 13.2 MJ DE/kg. Diets consisted primarily of wheat, barley, and soybean meal and were delivered to sows via a computerized feeding system (Big Dutchman; Pig Equipment GmbH, Vechta, Germany). Sows had ad libitum access to water via a drinker located in the feed trough in each farrowing crate. Piglets were weaned at approximately 28 d after farrowing.

Scoring Methodology

All measurements were taken by a single trained researcher (intra-observer repeatability = 90%) to eliminate inter-observer variation. Locomotory ability was recorded on transfer from the gestation accommodation to the farrowing facilities (-5 d). Limb and body lesions were recorded on -5 d, 24 h after entering the farrowing crate (-4 d), 10 d postpartum, and before weaning (28 d). Furthermore, claw lesions were recorded on -5 d and weaning, and behavioral observations were made on -5 , -4 , and 10 d.

Table 1. Description of the 6 different claw lesion scores developed by FeetFirst (Zinpro Corp., Eden Prairie, MN) as modified by Calderón Díaz et al. (2013)

Claw lesion category	Scores			
	0	1	2	3
Heel overgrowth and erosion	Normal	Slight overgrowth and/or erosion in soft heel tissue	Numerous cracks with obvious overgrowth and erosion	Large amount of erosion and overgrowth with cracks
Heel-sole crack	Normal	Slight separation at the juncture	Long separation at the juncture	Long and deep separation at the juncture
White line damage	Normal	Shallow and/or short separation along white line	Long separation along white line	Long and deep separation along white line
Horizontal cracks in the wall	Normal	Hemorrhage evident, short/shallow horizontal crack in toe wall	Long but shallow horizontal crack in toe wall	Multiple or deep horizontal crack(s) in toe wall
Vertical cracks in the wall	Normal	Short/shallow vertical crack in the wall	Long but shallow vertical crack in the wall	Multiple or deep vertical crack(s) in the wall
Dewclaw injuries	Normal	Short crack(s)	Long but shallow crack(s) in dewclaw wall	Multiple or deep crack(s) in dewclaw and/or partially or complete missing

Locomotory Ability

Locomotory ability was assessed using aspects of the procedure of Main et al. (2000) and included the evaluation of standing posture and gait. Sows were given a score of 0 (not lame) to 5 (severely lame, cannot stand) while they walked on the solid concrete floor of the 30-m-long passageway that connected the gestation accommodation to the farrowing facilities.

Claw Lesions

The hind claws are more often affected by claw lesions (Kroneman et al., 1993a; Jorgensen, 2000); therefore, only they were inspected while sows were lying in the farrowing crates. The lateral and medial claws were inspected and scored separately for lesions in the area of the toes, dewclaws, heels, and soles. The lesions were scored using the scale developed by FeetFirst (Zinpro Corp., Eden Prairie, MN) as modified by Calderón Díaz et al. (2013). The modifications comprised the inclusion of a score of 0 (normal) for all areas examined and a new type of lesion classification referred to as dewclaw injuries (Table 1). A total score for each sow for each lesion type/inspection was obtained by summing each lesion score.

Limb Lesions

Lesions on the front fetlock, carpal joint, humerus, elbow, carpus, hock, tarsus-metatarsus joint, hind fetlock, and metatarsus were scored according to their severity using the weighted scoring method of de Koning (1985), as modified by Boyle et al. (2000b). Lesions were classified under the following categories: 1) score

0 = normal; 2) score 1 = alopecia (hair loss) or callus (thickening of the epidermis and atrophy of glands); 3) score 2 = swellings (abnormal enlargement of a part of the body, typically as a result of an accumulation of fluid); 4) score 3 = wounds (where the epidermis is interrupted but not ulcerated and with no evidence of secondary infection) or bursitis (acquired fluid-filled sac that develops in the subcutaneous connective tissue, usually on the hind legs below the point of the hock or on the lateral sides of the elbow); 5) score 4 = severe wounds (these ulcerated lesions may or may not be accompanied by infection) or severe swellings (characterized by redness and swelling accompanied by heat and pain); and 6) score 6 = severe wounds plus severe swellings. The sum of scores for each lesion type yielded a total score for each sow for each lesion type/inspection time.

Body Lesions

Four body regions (ear, neck/shoulder, hindquarter, and belly/back) were examined on the left and right sides, along with the examination of the tail/anogenital region of every sow. Body lesions were scored as follows: 0 = no lesions; 1 = 1 small (approximately 2 cm), superficial lesion; 2 = more than 1 small or just 1 red (deeper than score 1) but still superficial lesion; 3 = 1 or several big (2 to 5 cm) and deep lesions; 4 = 1 very big (> 5 cm), deep, red lesion or many big, deep, red lesions; and 5 = many very big, deep, red lesions. The summation of scores across all examination sites yielded a total score for each sow/inspection.

Behavioral Observations

On -5 d, observations of lying-down behavior were made in accordance with Boyle et al. (2002) using 6 black-and-white cameras (WV-BP130/B; Sony Corp., Tokyo, Japan) installed on the ceiling of the farrowing rooms. The output from the cameras was recorded in real time (3-h mode) using a video cassette recorder (HS-1024; Mitsubishi Corp., Tokyo, Japan) and a video multiplexer (WJ-FS 216; Panasonic Corp., Osaka, Japan). In general, these recordings were made between 1100 and 1400 h. There was an approximate 10-min delay in starting the recording until all sows were secured in their crates. Information on latency (minutes) to lie down after entering the crate, number of attempts required, and time (seconds) taken to lie down were recorded. Lying down was classified according to the sequence of 3 movements described by Baxter and Schwaller (1983). Sows were classified as having attempted to lie down if either of the first 2 movements were observed without the occurrence of the third movement in the sequence. However, in some cases, sows were observed to begin the third movement in the sequence, but being unable to successfully slide 1 of their hind legs under the body, and they rapidly stood up again. In these cases, it was also considered that lying had been attempted. The analysis of sow behavior terminated once the sows lay down. On -4 and 10 d, sows were directly observed to record 1 lying event during the morning. Sows that were lying down or “dog” sitting were made to stand up and observed for a maximum of 30 min. The frequency of behaviors while standing (floor exploring, weight shift, and inactive) and attempts to lie down were recorded, as well as the latency and time taken to lie down.

Statistical Analysis

Data were analyzed using the sow as the experimental unit. All the observations were done once the sows were removed from their gestation accommodation and each sow was scored individually. Even though sows in this study ranged from 2 to 7 parities, sows were categorized as 2, 3, or ≥ 4 parities. Additionally, sows were categorized as nonlame (score ≤ 1) or lame (score ≥ 2). In addition, due to the low number of sows affected by severe wounds, severe swellings, and severe wounds plus severe swellings, these lesion scores were summed and reclassified into a single variable (severe lesions). Finally, medians (M_e) were calculated for claw, body, and limb lesions, and values were classified as less than or equal to the M_e or greater than the M_e lesion scores. Because BW, BCS, and backfat thickness were highly correlated (results not shown), only BW was included in the data analysis.

Data collected on -5 d (before entering the farrowing accommodation) were analyzed separately from the

data collected subsequently while the sows were in the farrowing crate. Predictor variables used in the analysis of data collected on -5 d included housing system during gestation, parity, and BW (included as a continuous variable). To analyze the data recorded during lactation, the predictor variables included in the model were housing system during gestation, flooring type during lactation, parity, observation day, interaction between housing system and flooring type, and BW (included as a continuous variable) with -5 d scores included as covariates in the model. In both analyses, only predictor variables with $P < 0.35$ remained in the final model.

Logistic binomial regression analysis (by the use of Wald statistics) was used to test the association among locomotory ability; claw, limb, and body lesions; and the predictor variables. Housing system during gestation and flooring type during lactation remained in the model regardless of the P -value to account for their potential influence on the predicted variables. Univariate models were used to identify the association between the different claw, limb lesions, and locomotory ability. Data were analyzed using PROC GENMOD of SAS (SAS Inst. Inc., Cary, NC). Statistical differences were reported at $P < 0.05$, and statistical trends were reported at $P \leq 0.10$. For locomotory ability, body, limb, and claw lesions results were reported as odds ratios with the associated 95% CI. An odds ratio greater than 1 is indicative of an increased risk, whereas an odds ratio less than 1 indicates a reduced risk. Results for continuous variables are reported as the regression coefficient (**REG**) with the associate SE.

The effects of housing system during gestation, flooring type in the farrowing crate, and lameness status on latency, time and number of attempts to lie down, as well as activities while standing, were analyzed using nonparametric tests. Each observation day was analyzed separately. Latency and time to lie down were analyzed using the Kruskal–Wallis test in PROC NPAR1WAY of SAS. Number of attempts to lie down (1 or ≥ 2 attempts), as well as the number of sows that lay down on -5 d before the video recording started, were analyzed with the frequency procedure of SAS. For the activities while standing, the average number of bouts/min was calculated and tested using PROC NPAR1WAY of SAS. Results on the behavioral observations are reported as median (M_e) with the associated interquartile range.

RESULTS

Thirteen sows (7 stall-housed sows and 6 loose-housed sows; all of which were on slatted steel flooring in the farrowing crate) were weaned early because of technical problems with the water distribution system due to low temperatures during winter 2010. Another stall-housed sow was weaned early because she was not

Table 2. Proportions of sows in each gestation-housing system affected by lameness and lesion scores greater than the median on the day of transfer from the gestation housing to the farrowing crates (–5 d)

	Median	Loose housing		Gestation stalls		Odds ratio ¹	95% CI	
		Number	Percent	Number	Percent		Lower	Upper
Claw lesions ^{2,3}								
HOE	6	24	55.8	12	29.3	2.4	0.92	5.99
HSC	2	15	34.9	16	39.0	0.8	0.30	1.85
WL	2	14	32.6	22	53.7	0.4 ^a	0.17	0.96
CWH	3	12	27.9	20	48.8	0.4 ^a	0.15	0.99
CWV	2	10	23.3	15	36.6	0.5	0.20	1.36
DCI	4	12	27.9	24	58.5	0.3 ^a	0.10	0.68
Body lesions ⁴	7	38	88.4	3	7.1	62.9 ^a	15.47	255.38
Limb lesions ⁵								
Alopecia	2	11	25.6	10	23.8	1.6	0.59	4.58
Callus	4	13	30.2	24	57.1	0.3 ^a	0.14	0.82
Swelling	2	14	32.6	13	31.0	1.1	0.45	2.79
Wound	0	22	51.2	14	33.3	2.2	0.88	5.36
Bursitis	0	24	55.8	16	38.1	0.2	0.9	5.56
Severe lesions	0	11	25.6	7	16.7	1.8	0.61	5.14

¹Odds ratios reported for loose housing system compared to gestation stalls.

²Total of each lesion score (refer to Table 1 for description of scores for each claw lesion category).

³HOE = heel overgrowth and erosion; HSC = heel-sole crack; WL = white line damage; CWH = horizontal cracks in the wall; CWV = vertical cracks in the wall; and DCI = dewclaw injuries.

⁴Cumulative score of lesions observed on the ear, neck/shoulder, rump, hindquarter, and belly/back for both left and right sides of the sow, as well as the tail/anogenital region (0 = normal to 5 = severely injured).

⁵Lesions observed on the front fetlock, carpal joint, humerus, elbow, carpus, hock, tarsus-metatarsus joint, hind fetlock, and metatarsus (0 = normal to 6 = severe injuries).

^aSignificantly different from reference category; $P < 0.05$.

eating and a loose-housed sow was weaned early due to a severe wound on the hind fetlock. Therefore, data for the weaning inspections of these sows are missing. Additionally, a stall-housed sow died suddenly during lactation for unknown reasons.

Factors Associated with Locomotory Ability

Over 74% of loose-housed sows and 33% of stall-housed sows were categorized as lame. Thirty-nine sows (11 loose-housed sows and 28 stall-housed sows) were nonlame (lameness score ≤ 1), and 46 sows (32 loose-housed sows and 14 stall-housed sows) were classified as lame. Among the lame sows, 16 sows (13 loose-housed sows and 3 stall-housed sows) were severely lame (lameness score ≥ 3). Consequently, sows loose-housed during gestation had a greater (odds ratio = 4.51; $P < 0.01$) risk of lameness than stall-housed sows. In addition, there was a tendency for an increased ($P = 0.09$) risk of lameness (REG = 0.011 ± 0.007) with every 1 kg increase in BW on –5 d.

Factors Associated with Claw Lesions

When inspected in the farrowing crates on –5 d, loose-housed sows had a reduced ($P < 0.05$) risk of

claw lesions, particularly white line damage, horizontal cracks in the walls, and dewclaw injuries, but tended to have a greater ($P = 0.07$) risk of heel overgrowth and erosion, compared to stall-housed sows (Table 2). Third parity sows had an increased ($P < 0.05$) risk of vertical cracks in the wall (odds ratio = 3.41) compared to second-parity sows; however, there were no ($P > 0.05$) associations between the 6 types of claw lesions and lameness (results not shown). Before weaning, all the claw lesions recorded, except heel overgrowth and erosion and white line damage, received greater scores than on –5 d (Tables 2 and 3). Also, there was a tendency for a reduced ($P = 0.08$) risk of white line damage and a tendency for an increased ($P = 0.08$) risk of vertical cracks in the wall associated with loose-housed sows compared to stall-housed sows (Table 3). Furthermore, sows housed on cast iron floor during lactation had a reduced risk of heel overgrowth and erosion ($P < 0.01$), heel-sole crack ($P < 0.01$), and horizontal cracks in the wall ($P < 0.08$) compared to sows housed on slatted steel floors. Third-parity sows had a greater risk of heel overgrowth and erosion ($P < 0.01$) and vertical cracks in the wall ($P = 0.08$) than second-parity sows. When compared to sows with lesion scores below the M_c on entry to the farrowing crates, sows with greater than M_c scores for heel

Table 3. Differences between gestation housing-systems, floor type during lactation, parity, day of inspection, lesion scores on transfer to farrowing crates (–5 d), and BW on body, limb, and claw lesions greater than the median of sows during lactation

	Day of inspection ⁴												Score when entering farrowing crate (–5 d) ⁵					
	Housing system during gestation ¹			Floor type during lactation ²			Parity ³			10 d postpartum			Before weaning			REG ⁷	SE	BW ⁶
	Odds ratio	95% CI		Odds ratio	95% CI		Odds ratio	95% CI		Odds ratio	95% CI		Odds ratio	95% CI				
Body lesions ⁸	1.0	0.38 to 5.54		1.2	0.64 to 2.25	NI ¹²	NI	NI	NI	0.4 ^a	0.18 to 0.78	0.4 ^a	0.17 to 0.88	8.9 ^a	0.34 to 23.49	0.01	0.05	
Limb lesions ⁹																		
Alopecia	1.1	0.54 to 2.14		12.1 ^a	0.54 to 26.99	NI	NI	NI	0.4 ^a	0.19 to 0.81	1.2	0.59 to 2.30	0.4 ^a	0.18 to 0.98	NI	NI	NI	
Callus	1.8	0.99 to 3.47		1.7	0.82 to 3.34	2.0 ^a	1.04 to 3.79	0.7	0.32 to 1.61	1.5	0.81 to 2.65	2.1	1.08 to 4.25	2.3 ^a	1.22 to 4.35	NI	NI	NI
Swelling	0.7	0.36 to 1.31		0.6	0.32 to 1.21	0.7	0.32 to 1.66	1.9	0.87 to 4.07	1	0.48 to 1.99	1.6	0.83 to 3.23	1.5	0.78 to 2.83	NI	NI	NI
Wound	0.7	0.23 to 1.26		1.2	0.67 to 2.21	NI	NI	NI	NI	1.4	0.66 to 2.94	2.9 ^a	1.31 to 6.33	1.7	0.94 to 3.10	0.01 ^a	0.004	
Bursitis	0.4 ^a	0.17 to 0.73		1.2	0.65 to 2.36	NI	NI	NI	NI	1.7	0.86 to 3.31	1.8	0.82 to 3.93	5.3 ^a	2.56 to 10.89	NI	NI	NI
Severe lesions	3.5 ^a	1.48 to 8.47		0.9	0.31 to 2.41	NI	NI	NI	NI	0.6	0.27 to 1.56	0.3 ^a	0.11 to 0.81	11.7 ^a	4.56 to 30.17	NI	NI	NI
Claw lesions ^{10, 11}																		
HOE	1.4	0.40 to 5.01		0.1 ^a	0.03 to 0.55	9.4 ^a	1.57 to 56.08	2.1	0.32 to 13.78	–	–	–	–	6.0 ^a	1.33 to 26.66	0.01	0.01	
HSC	1.2	0.36 to 4.26		0.3 ^a	0.08 to 1.02	2.0	0.45 to 8.84	0.42	0.07 to 2.34	–	–	–	–	7.6 ^a	1.97 to 29.26	–0.01	0.01	
WL	0.4	0.14 to 1.12		0.7	0.24 to 1.93	NI	NI	NI	NI	–	–	–	–	2.0	0.70 to 5.77	NI	NI	
CWH	1.1	0.34 to 3.25		0.4	0.13 to 1.14	NI	NI	NI	NI	–	–	–	–	2.2	0.70 to 6.95	0.02 ^a	0.01	
CWV	3.0	0.85 to 10.87		0.8	0.23 to 2.93	7.5 ^b	1.23 to 46.25	3.76	0.53 to 26.45	–	–	–	–	5.1 ^a	1.30 to 20.18	0.01	0.01	
DCI	0.8	0.26 to 2.12		1.2	0.42 to 3.38	NI	NI	NI	NI	–	–	–	–	NI	NI	0.01	0.01	

¹Odds ratios reported for loose housing system compared to gestation stalls.

²Odds ratios reported for east iron system compared to slatted steel.

³Odds ratios reported for sows parity 3 and parity ≥ 4 compared to sows parity 2.

⁴Odds ratios reported for 10 d postpartum and before weaning compared to 24 h after entering farrowing crates

⁵Odds ratios reported for lesion scores greater than the median compared to lesion scores less or equal than the median on entering farrowing crates (–5 d).

⁶Included in the model as continuous variable reported; results reported as the regression coefficient and standard error

⁷Coefficient of regression.

⁸Cumulative score of lesions observed on the ear, neck/shoulder, rump, hindquarter, and belly/back for both left and right sides of the sow, as well as the tail/anogenital region (0 = normal to 5 = severely injured).

⁹Lesions observed on the front fetlock, carpal joint, humerus, elbow, carpus, hock, tarsus-metatarsus joint, hind fetlock, and metatarsus (0 = normal to 6 = severe injuries).

¹⁰Total of each lesion score (refer to Table 1 for description of scores for each claw lesion category).

¹¹HOE = heel overgrowth and erosion; HSC = heel-sole crack; WL = white line damage; CWH = horizontal cracks in the wall; CWV = vertical cracks in the wall; and DCI = dewclaw injuries.

¹²NI = not included in the final model; $P > 0.35$.

^aSignificantly different from reference category; $P < 0.05$.

Table 4. Differences between gestation-housing systems, floor type during lactation, and lameness status on median (interquartile range) time and latency to lie down

	Housing system during gestation		Floor type during lactation		Lameness status ¹	
	Loose housing	Gestation stalls	Slatted steel	Cast-iron	Non-lame	Lame
Day of transfer to farrowing crate (-5 d)						
Time to lie down, s	19.5 (15.0)	17.0 (20.0)	18.0 (15.0)	17.0 (22.0)	22.0 (19.0)	15.0 (13.0)
Latency to lie down, min	14.1 (10.7)	19.4 (20.5)	15.5 (11.0)	17.5 (13.4)	20.5 (18.7) ^a	14.1 (10.7) ^b
24 h after entering farrowing crate (-4 d)						
Time to lie down, s	12.0 (12.0)	18.0 (15.0)	15.5 (12.5)	15.5 (13.5)	16.0 (13.0)	15.0 (13.0)
Latency to lie down, min	3.3 (3.38) ^a	7.0 (8.8) ^b	5.3 (9.1)	4.4 (5.2)	5.0 (9.0)	4.0 (5.3)
10 d postpartum						
Time to lie down, s	11.5 (9.0)	12.0 (16.0)	12.5 (8.0)	10.0 (11.0)	11.0 (11.0)	12.0 (9.0)
Latency to lie down, min	5.1 (6.3)	5.3 (5.0)	5.7 (7.0)	4.3 (5.5)	5.2 (4.7)	5.0 (7.0)

¹Sows were categorized as nonlame (score ≤ 1) or lame (score ≥ 2) based on a 6-point lameness scale (0 = not lame to 5 = severely lame, cannot stand).

^{a,b}Within a row and main effect, medians lacking common superscript letters differ; $P < 0.05$.

overgrowth and erosion, heel-sole crack, and vertical cracks in the wall had even greater ($P < 0.01$) risks for these claw lesions at weaning. In addition, there was an increased risk of horizontal cracks in the wall ($P < 0.05$) and dewclaw injury ($P = 0.07$) associated with a 1 kg increase in BW on entering the farrowing crates (-5 d).

Factors Associated with Limb Lesions

On -5 d, there was a reduced ($P < 0.01$) risk of caluses, but there were tendencies for an increased risk of wounds ($P = 0.09$) and bursitis ($P = 0.08$) in loose-housed sows relative to stall-housed sows (Table 2). There was a tendency for a greater ($P = 0.08$) risk of bursitis (odds ratio = 2.94) in sows having 4 or more litters compared to second-parity sows; however, there were no ($P > 0.05$) associations between limb lesions and lameness (results not presented).

During lactation, sows loose-housed during gestation had a greater risk of developing calluses ($P = 0.05$) and severe lesions ($P < 0.01$), but a reduced risk for bursitis ($P < 0.01$), than stall-housed sows (Table 3). Additionally, sows housed on cast iron floor during lactation had an increased ($P < 0.01$) risk of alopecia compared to sows housed on slatted steel floor. Even though the risk of alopecia decreased between -4 d and 10 d postpartum, there was an increased risk of calluses ($P < 0.05$) and wounds ($P < 0.01$), as well as a reduced ($P < 0.01$) risk of severe lesions, at weaning than on -4 d. Third-parity sows were at a greater ($P < 0.01$) risk of calluses than second-parity sows, whereas sows of parity ≥ 4 tended to have an increased ($P = 0.10$) risk of swellings compared to second-parity sows.

There was an increased ($P < 0.01$) risk of wounds on the limbs associated with an increase of 1 kg BW on -5 d. In addition, sows entering the farrowing crates (-5 d) with greater than M_c scores for alopecia, callus, bursitis, and severe limb lesions continued to have greater (P

< 0.01) scores for these lesions as lactation progressed compared to sows entering the farrowing crates with limb lesion scores which were less than M_c .

Factors Associated with Body Lesions

On entering the farrowing crates (-5 d), there was an increased ($P < 0.01$) risk of body lesions associated with sows loose-housed during gestation compared with stall-housed sows (Table 3). There was no ($P > 0.05$) association between BW and body lesion scores on -5 d, or between housing systems ($P > 0.05$). Also there was no association between flooring type ($P > 0.05$) and body lesion scores during lactation. However, the risk of body lesions was reduced ($P < 0.01$) at 10 d postpartum and before weaning compared to scores from -4 d. Moreover, sows with body lesion scores greater than M_c later in the study were more likely to have had higher ($P < 0.01$) lesion scores when transferred to the farrowing crate than sows with body lesions less than or equal to the M_c on entry to the farrowing crates. The risk of body lesion scores tended to increase ($P = 0.06$) with an increase of 1 kg of BW on -5 d.

Behavioral Observations

There were no ($P > 0.05$) effects of housing system during gestation or of flooring type during lactation on the number of sows that lay down before the video recording started after entering the farrowing crates (results not presented). However, more ($P = 0.06$) sows classified as lame were observed lying down than non-lame sows (19 vs. 6) before the beginning of video recording. Loose-housed sows tended to have a shorter ($P = 0.06$) latency to lie down than stall-housed sows, and lame sows had a shorter ($P < 0.01$) latency to lie down than nonlame sows (Table 4) on -5 d. Conversely, flooring type during lactation had no ($P > 0.05$) effect on la-

Table 5. Differences between gestation-housing systems, floor type during lactation, and lameness status on median (interquartile range) for average number bouts/min sows were inactive, shifted their weight between limbs, and perform behaviors toward the floor

	Housing system during gestation		Floor type during lactation		Lameness status ¹	
	Loose housing	Gestation stalls	Slatted steel	Cast-iron	Non-lame	Lame
24 h after entering farrowing crate (-4 d)						
Inactive	0.5 (1.2) ^a	0.3 (0.4) ^b	0.3 (0.6)	0.4 (1.2)	0.4 (0.8)	0.4 (0.8)
Weight shift	2.3 (4.7) ^a	1.0 (2.6) ^b	1.1 (4.2)	1.6 (4.9)	2.1 (4.0)	1.1 (4.9)
Behavior toward the floor	1.2 (2.6)	0.6 (1.3)	0.6 (2.7)	0.9 (2.9)	0.7 (2.8)	0.9 (1.7)
10 d postpartum						
Inactive	0.2 (0.4)	0.2 (0.5)	0.2 (0.3)	0.3 (0.9)	0.2 (0.5)	0.3 (0.5)
Weight shift	0.9 (3.5)	0.9 (1.5)	1.0 (1.8)	0.8 (3.5)	0.8 (1.6)	1.0 (2.0)
Behavior toward the floor	0.6 (0.9)	0.5 (1.3)	0.5 (0.8)	0.7 (1.4)	0.5 (0.7)	0.6 (1.4)

¹Sows were categorized as nonlame (score ≤ 1) or lame (score ≥ 2) based on a 6-point lameness scale (0 = not lame to 5 = severely lame, cannot stand).

^{a,b}Within a row and main effect, medians lacking common superscript letters differ; $P < 0.05$.

tency to lie down, and neither housing system, floor type, nor lameness status affected ($P \geq 0.31$) the number of attempts or time taken to lie down on -5 d.

Even though loose-housed sows had a shorter ($P < 0.01$) latency to lie down than stall-housed sows 24 h after entering the farrowing crates, neither floor type nor lameness status affected ($P > 0.05$) the latency to lie down on -4 d (Table 4). In addition, housing system during gestation, floor type during lactation, and lameness status did not ($P \geq 0.10$) affect the number of attempts to lie down and time to lie down on -4 and 10 d postpartum, as well as latency to lie down at 10 d postpartum.

After 1 d in the farrowing crates, inactivity ($P < 0.05$), number of weight shifts between limbs ($P = 0.05$), and behavior directed toward the floor ($P = 0.06$) while standing were greater in loose-housed than in stall-housed sows (Table 5). However, there was no ($P > 0.05$) effect of flooring type during lactation or lameness status on the number of times sows were inactive, shifted weight between limbs, or expressed behavior directed toward the floors while standing. Additionally, at 10 d postpartum, neither the number of times sows were inactive, shifted weight between their limbs, nor behavior directed toward the floors while standing was affected ($P > 0.05$) by housing system, floor type, or lameness status.

DISCUSSION

Sows which were loose housed during gestation had a greater risk of being lame on transfer to the farrowing crate. Similar findings were reported in several studies (Anil et al., 2005; Harris et al., 2006) where sows kept in groups without bedding experienced more locomotory problems compared with sows kept in stalls during gestation. Loose housing of sows places high demands on the locomotory system (Kroneman et al., 1993b). Of the loose-housed sows classified as lame on transfer to

the farrowing crate, 41% were severely lame (none were nonambulatory and all severely lame sows were on a program of veterinary care which included anti-inflammatory drugs, analgesics, topical sprays, and antibiotics, if required). In the present study, loose-housed sows were housed in a dynamic group with new sows entering the group at frequent intervals, such that the composition of the group was constantly changing. This was associated with high levels of aggression as the sows fought to establish the new hierarchical social system (Lambert et al., 1986; Simmins, 1993) and partially explains the high levels of lameness (Deen et al., 2005). The risk of lameness in loose-housed sows is further exacerbated if the floor does not provide adequate support to the claws during an aggressive interaction (Spoolder et al., 2009). Indeed, the slats in the loose house, while in compliance with EU legislation, were the narrowest available for sow housing (80 mm), and there is a good deal of anecdotal evidence that such slats are associated with more lameness than wider ones (up to 140 mm; Boyle et al., 2012). It is unlikely that a severely lame sow would have recovered completely by the time new sows were introduced to the group. In any case, these lame sows still had to walk around on slats to access resources, such as feed and water, and, as such, there was little opportunity for their lameness to resolve between disruptions to the group composition.

In agreement with many studies, loose-housed sows had greater body lesion scores than stall-housed sows on the day of transfer to the farrowing crates (Gjein and Larssen, 1995; Anil et al., 2003; Harris et al., 2006). This was expected as it reflected the aggression that the loose-housed sows were exposed to at each remixing. Once the sows were moved to the farrowing crate, the possibility of an aggressive encounter was eliminated; thus, the risk of body lesions decreased with the progression of the lactation period. The risk of incurring body lesions in the far-

rowing crate was similar for all sows regardless of their gestation accommodation but, in accordance with Anil et al. (2003), the risk was higher in heavier sows. Most of the body lesions recorded during lactation were superficial scratches caused by the crate fixtures and fittings. The movement of heavier/larger sows is severely restricted in the confines of a farrowing crate, which increases their risk of incurring such injuries (Anil et al., 2002).

Anil et al. (2007) suggested that the type and amount of activities performed by sows may determine the type and severity of claw lesions. As these 2 factors varied considerably between the loose- and individual-housing systems, it is not surprising that several differences were found in measures of claw health. Claw lesions on the heel area, such as overgrowth and erosion, were more likely to receive higher scores in loose-housed than stall-housed sows on transfer to the farrowing crate. These lesions are associated with the abrasive forces applied to the heel while walking/fighting on slatted concrete (Ossent, 2010). In contrast, sows housed in stalls during gestation were at higher risk of white line damage. It is possible that floor hygiene might have influenced the development of this lesion (Manske, 2002). The hind feet of the stall-housed sows were more exposed to feces and urine than those of the loose-housed sows which were able to move around and spent a lot of time in the solid-floored resting areas that were mostly dry and clean. Standing in feces and urine not only reduces claw hardness (Sobestiansky et al., 1999; KilBride et al., 2010), but can also cause chemical erosion on the heel and sole areas of the claw (Bergsten, 2001). As the white line is the weakest part of the claw (Budras et al., 1996), these factors could manifest in damage to this region. Additionally, stall-housed sows were more likely to have horizontal cracks in the wall and injured dewclaws on transfer to the farrowing crate. Sows in gestation stalls can have severe maneuvering difficulties in the restricted space (Marchant and Broom, 1996a; Boyle, 2008), which increases the chance of the weight-bearing claws and dewclaws getting caught between the slats, thereby increasing the risk of cracks and injuries.

Claw health deteriorated in the farrowing crate irrespective of flooring type. This is likely because both floors were fully slatted with large void ratios which increase the pressure applied per unit area of the claw (Anil et al., 2007). The void areas were 45% and 32% for the slatted steel and cast iron, respectively. According to Webb (1984), void ratios greater than 40% are particularly detrimental to the health of the heel region, which could partly explain the increased risk of heel overgrowth and erosion and heel-sole cracks associated with the slatted steel floor. Yet, in addition to the higher void ratio, slatted steel floors are more abrasive (O'Connell et al., 1996), offer poorer grip (Nooyen Pig

Flooring, personal communication, 24 October 2012), and are also detrimental for piglet welfare (Lewis et al., 2005). The reason the risk of certain claw injuries (horizontal cracks in the walls) was greater for heavier sows housed on such types of slatted floors is likely because the pressure applied per unit area of the claw is even greater for heavier sows (Anil et al., 2007). These authors reported a similar association between cracks in the wall and BW at d 109 of gestation.

Parity of the sows influenced particular claw lesions. For example, third-parity sows were at greater risk of cracks in the wall compared to second-parity sows, which is in agreement with Pluym et al. (2011). However, there was no difference between second- and ≥ 4 -parity sows. It is possible that sows with severe claw lesions do not reach the fourth parity (i.e., they may be culled from the herd for lameness); hence, sows that survive in the herd until the fourth parity may have undergone a selection process for good claw health.

In agreement with other authors (Anil et al., 2007; Enokida et al., 2011; Pluym et al., 2011), all the sows in this study had at least 1 claw lesion. However, in spite of the fact that claw lesions are considered a major cause of lameness in sows (Dewey et al., 1993; Anil et al., 2007), there was no relationship between claw lesions and lameness. It is important to note that M_e scores were mild to moderate for all claw lesions except for heel overgrowth and erosion and dewclaw injury which had M_e scores indicative of severe. Anil et al. (2007) reported that sows with white line lesions were more likely to be lame, but they evaluated the presence or absence of the lesion and disregarded the potential effect of lesion severity. In the current study, the scores assigned to the 4 claws were used in the analysis because there were so few sows without lesions. When examining piglet claws postmortem, KilBride et al. (2009b) reported that internal damage was often more severe than the visual scores attributed to lesions postmortem. However, it is possible that the converse is also true: lesions that look serious on the exterior, and therefore receive higher scores, do not necessarily extend into the corium and cause discomfort leading to lameness. Future work of this kind should include postmortem examinations of sows claws to ascertain how the severity of exterior lesions relate to the degree to which they penetrate the corium.

In contrast to body lesions, lesions to the limbs are generally induced environmentally (Boyle, 1997; KilBride, 2008); however, they are indirectly mediated by aggression in loose-housed sows (Anil et al., 2005). Hence, the tendency for a higher likelihood of having wounds combined with the lower risk of having calluses in loose-housed sows on the day of entry to the farrowing accommodation likely reflects traumatic contacts between the limbs and concrete during aggressive encoun-

ters. Interestingly, loose-housed sows had a tendency for higher scores for bursitis on -5 d, but they were at lower risk of bursitis during the lactation period. Bursitis M_e scores before entering the farrowing crate (-5 d) were equal to 0, meaning that sows classified with greater than M_e scores had at least 1 area of the limbs affected by bursitis, whereas, during lactation, the bursitis M_e score was equal to 3, indicating that sows classified with greater than M_e scores had at least 2 areas of the limbs affected by bursitis. The number of loose-housed sows with at least 1 bursa did not vary during the experiment, while the number of stall-housed sows with at least 1 bursa increased during lactation (results not shown). Therefore, some sows from both gestation housing systems that had at least 1 bursa on -5 d developed further bursal lesions during lactation, which increased the M_e score. This result is in agreement with the result reported by KilBride et al. (2009a) that the prevalence of bursitis increased as the lactation period progressed; however, the cause of the development of new bursal lesions in this study is unclear. KilBride et al. (2009a) suggested that floors used in farrowing crates may be hard enough to cause bursa to develop, yet no association between floor type during lactation and bursitis was found in the present study. In fact, no association between farrowing house floor type and any of the limb lesions (apart from alopecia) was found, which is in contrast to the findings of KilBride et al. (2009a). In addition, no association between lameness and any of the limb lesions was found, which is contrary to the results of KilBride et al. (2009a, 2010) and Calderón Díaz et al. (2013).

Although there was no difference in the number of attempts required to lie down between gestation housing systems, loose-housed sows had a shorter latency to lie down on -5 and -4 d than stall-housed sows. Loose housing provides sows with constant access to exercise, increasing muscle and bone strength (Marchant and Broom, 1996b) and sow agility (Marchant and Broom, 1996a; Schenck et al., 2008), thereby improving sow maneuvering ability in farrowing crates (Boyle et al., 2002). However, it could also be possible that the shorter latency to lie down in loose-housed sows was because they were lamer; lame sows had a shorter latency to lie down than nonlame sows. Indeed, Berg and Sanotra (2003) found a negative correlation between time standing and lameness score in broiler chickens, and KilBride et al. (2009a) reported that lame sows spend more time lying down. Sows loose housed during gestation are more stressed by confinement in farrowing crates than sows housed individually during gestation (Boyle et al., 2000a). The higher levels of inactivity and behavior directed toward the floor while standing in loose-housed sows the day after they entered the farrowing accommodation (-4 d) may reflect some difficulties habituating to close confinement.

In contrast, it is more likely that the higher frequency of weight shifting in these sows reflected the fact that they had greater claw lesion scores in the heel area (Neveux et al., 2003); however, this relationship was not tested and needs further investigation. In agreement with Boyle et al. (2002), lying-down behavior and activities while standing did not differ between treatments after 10 d in the farrowing crate, indicating that the sows habituated to the behavioral restriction over time.

In conclusion, the findings of this study suggest that lameness is likely to become more of a problem when pregnant sows are housed loose in groups without bedding, especially on slatted floors. Nevertheless, it is important to emphasize that the loose sows used in this study originated from 1 group, and it is possible that particular social features of the group (presence of some inordinately aggressive sows) or environmental features of the house fixtures and fittings may have exacerbated the problems with lameness. Although the extent of the discomfort they cause requires further investigation, the high prevalence of claw lesions, regardless of gestation housing system, is a welfare concern. Further research is required on the pathological causes of lameness in sows. In spite of the growing interest in loose-farrowing pens, farrowing crates will likely persist for the immediate future. Regardless of the flooring type, the use of fully slatted floors with high void areas in farrowing crates has a detrimental effect on claw health. Therefore, to ensure that lameness problems associated with loose housing on slats during gestation are not exacerbated, it is imperative that alternative floors which do not pose a risk to claw health are investigated for use in farrowing crates.

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