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Evaluation of crates and girth tethers for sows: reproductive performance, immunity, behavior and ergonomic measures

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Abstract

An evaluation of reproductive performance, behavior, immunity and ergonomics was conducted for two common sow housing systems: the girth tether and crate. Littermate Yorkshire×Landrace gilts were randomly assigned to either the crate or girth tether system and they remained in that treatment for two consecutive pregnancies and lactations. A total of 171 matings resulted in 141 litters (82.4% farrowing rate). Second parity sows penned in girth tethers had 1.5 fewer piglets born and 1.3 fewer piglets weaned than sows in the crate system ($P<0.05$). Owing to smaller litter sizes, piglets of nursing sows in the girth tether system were heavier ($P<0.01$) at weaning. Immune measures showed no treatment effects. Behavioral measures indicated crated gilts and sows were more active overall ($P<0.01$) than girth tethered sows. In addition, sows in the gestation crate showed more ($P<0.05$) oral/nasal stereotypies, sitting and drinking than sows in the girth tether system. Less time was required to catch litters of piglets ($P<0.05$) in the girth tether than in the crate farrowing environment. We concluded that the girth tether system we evaluated was undesirable from a welfare and economic standpoint, and use should be discouraged on commercial farms. In sharp contrast, the crate systems induced no evidence of stress among our sows as measured by reproductive and immune parameters. Finally, expression of large amounts of oral/nasal stereotypies were associated with enhanced litter size.

Key words: Pig; Behavior; Welfare; Gestation crate; Girth tether

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1. Introduction

Sows are housed in a wide variety of systems around the world. Some countries in Europe have banned or are phasing out individual housing of pregnant sows. Even so, the gestation crate (also called a stall) supports a high reproductive rate (Pig Improvement Company, 1993) and is becoming the most common housing system in the United States. Tethers come in two styles: neck and girth tether. We have found in past work, that the neck tether supports a lower reproductive rate than the crate (McGlone et al., 1988). The girth tether has been studied less often than the neck tether and pork producers suggested that the girth tether may affect the sow differently than a neck tether. Reproductive performance, immune function and behavior of sows in these common housing systems were compared, and an estimate of the human labor required for these systems, so informed decisions could be made on the merits of each.

Many studies have examined common sow housing systems for their effects on sow behavior, reproduction and physiology. Sows housed in neck tethers have been shown in a number of laboratories to show acute elevated adrenal activity compared with sows in stalls or group housing systems (Becker et al., 1985; Barnett et al., 1991). However, few studies included more-sensitive measures of immunity to assess potentially stressful environments.

Past work that examined measures of immunity typically measured antibody titers. In our experience, relatively severe stressors are required to suppress antibody synthesis in the pig. Natural killer cells (NK) are a population of lymphocytes that spontaneously kill viral-infected or malignant cells (Trinchieri, 1989). NK cells are very sensitive to stress-induced suppression. For example, pigs from a commercial farm that experienced shipping stress showed zero NK cell activity (McGlone et al., 1993).

Decisions about sow housing must involve the consideration of the welfare of the sow as well as economics. While recent studies have evaluated behavioral and physiological responses to different types of sow housing (Barnett et al., 1987a,b, 1991), the studies have not included the measurement of stereotyped behavior. Because of difficulties in interpreting certain behaviors, particularly stereotyped bar biting and other oral/nasal repetitive behaviors, this work might lead to a better understanding of these behaviors. Correlations were calculated to generate hypotheses about behavioral–physiological relationships that could be tested in future work.

2. Animals, materials and methods

2.1. Animals and housing systems

Gilts were Yorkshire×Landrace crossbred genotype, which had been raised in group pens in confinement in a standard commercial environment (total slats, mechanical ventilation). One-hundred-and-seventy-one littermate gilts were

randomly assigned to one of the housing systems; girth tethers or dry sow stalls. Females were fed a 14% crude protein diet during development, gestation and lactation. The diets were sorghum–soybean meal based and formulated to meet the National Research Council (NRC, 1988) requirements for each phase. During development and lactation, the females were fed ad libitum and in gestation the females were fed 2 kg daily. Every attempt was made to begin the study with gilts that were similar in terms of genotype and rearing environment.

2.2. Reproductive performance measures

The gilts were raised in pens from weaning to puberty. After the gilts were bred, they were moved to either a gestation crate or girth tether in a totally enclosed, environmentally controlled building. The animals remained on the same housing treatment throughout gestation and lactation for two consecutive parities. Failure to detect oestrus was a measure considered only for sows, as gilts were placed on the treatments if they had been bred. Farrowing rate was the percentage of bred females that farrowed. For second parity sows, some were not detected in oestrus after weaning while others were bred, but did not become (or remain) pregnant. For sows, failure to detect oestrus by 20 days after weaning was considered 'not detected in oestrus'. Five days before the females were due to farrow, they were moved into a totally enclosed, environmentally controlled farrowing facility. During lactation the gilts and sows had access to a self-feeder. The amount of feed added to the feeder was measured daily. The piglets were weaned after a 28 day lactation. Measurements recorded for the farrowing phase included number of pigs born, number of pigs born live, litter birth weight, number of pigs weaned, litter weaning weight, average weaning weight, mortality, and sow weight loss. The number of days from weaning until the sows expressed oestrus was recorded.

2.3. Immune measures

Twenty milliliters of blood were obtained over sodium heparin 1 week before farrowing (gestation barn) and 3 weeks after farrowing (farrowing barn). Blood samples were assayed for NK cell activity, antibody response to sheep red blood cells (SRBC) and differential counts. Blood smears were made using whole blood. The smears were fixed in methanol and stained with Hemo-3 (Biochemical Sciences, Bridgeport, NJ, USA) for differential white cell counts. One hundred cells were counted per slide. At a 1:500 dilution, the number of white blood cells (WBC) was counted using a Coulter cell counter (Coulter Electronics, Hialeah, FL, USA).

A hemagglutination assay was used to determine antibody response to SRBC. Animals were injected with 1 ml of 40% SRBC 2 weeks before farrowing and 2 weeks after farrowing. Blood samples were obtained 7 days post injection. The plasma samples were thawed and heat inactivated in 57°C water bath for 30 min. The heat inactivated samples (200 μl) were placed in the first wells of each round-

bottom plate in duplicate. One hundred μl of phosphate buffered saline (PBS) was added to all wells. The plates were diluted by removing 100 μl of each sample with the octapipette and serially diluting each well from left to right across the plate. The final 100 μl was discarded. To each well, 100 μl of 1% SRBC was added and the plates were agitated for 1.5 min. The plates were covered and incubated at room temperature for 24 h. The titers were determined by the sedimented cells forming a distinct pattern on the bottom of the wells. The highest dilution giving a positive reaction determined the titer.

The NK cell assay was performed according to standard techniques for porcine NK assay (Lumpkin and McGlone, 1992). Twenty milliliters of blood were centrifuged for 20 min at 850 *g*. The buffy coat, containing the peripheral blood mononuclear cells (PBMC), was removed and mixed with Roswell Park Memorial Institute (RPMI) 1640 (Sigma Chemical, St Louis, MO, USA; with 2.0 g l^{-1} of NaHCO3 and 100 U ml^{-1} of gentamicin sulfate). The buffy-coat–RPMI mixture was layered onto 4 ml of histopaque 1077 (Sigma Chemical) and centrifuged at 400 *g* for 30 min at 25°C. The PBMC were collected and washed once in RPMI at 850 *g* for 15 min. Adherent monocytes were removed by adherence to sterile plastic Petri dishes for 2 h in a 5% CO_2 humidified chamber. Non-adherent PBMC were collected by gently rinsing Petri dishes with RPMI then centrifuging recovered cells for 15 min at 850 *g*. The recovered PBMC were resuspended in 1 ml of RPMI and were counted on a Coulter Counter (Coulter Electronics, Hialeah, FL, USA). The samples were diluted in RPMI supplemented with 10% fetal bovine serum (FBS) (Sigma Chemical) and adjusted to a cell concentration of 1×10^7 cells ml^{-1}.

The targets for the assays were K-562 cells from a human chronic myelogenous leukemia cell line (American Type Culture Collection, Rockville Pike, MD, USA). The targets were maintained in log growth in RPMI–10% FBS. Target cells were labeled with ^{51}Cr by incubating 5×10^6 cells in 1 ml of RPMI–10% FBS with 100 μCi of ^{51}Cr for 1 h in 5% CO_2. After 1 h, 10 ml of RPMI–10% FBS was added and targets were incubated an additional 1 h. The target cells were pelleted and washed twice and resuspended in RPMI–10% FBS to a final concentration of 1×10^5 cells ml^{-1}.

Samples were run in triplicate at effector:target ratios (E:T) of 12.5:1, 25:1, 50:1 and 100:1; 10^4 target cells were added to each well. Total volume per well was 200 ml. Maximum ^{51}Cr release was determined by adding 100 ml of 7.5% Triton-X detergent (Sigma Chemical) to lyse all targets. Spontaneous ^{51}Cr release was determined by adding 150 ml of RPMI–10% FBS to target cells and counting radioactive label in the supernatant. Plates were incubated in a 5% CO_2 humidified chamber for 18 h. Plates were centrifuged for 10 min at 125 *g*. One hundred microliters of supernatants were collected and transferred to a plastic tube. Each tube was counted for 1 min on a gamma counter.

Percentage of cytotoxicity was calculated using the following formula: [(experimental release cpm — spontaneous release cpm)/(maximum release cpm — spontaneous release cpm)] × 100.

2.4. Behavior during gestation

Each gilt or sow was time-lapse videotaped for 24 h, for two parities. The tapes were viewed by trained observers. Standing, sitting, lying, feeding, drinking and oral/nasal behaviors were recorded. Each behavior was assigned a number and entered into a behavior-recording program described by McGlone et al. (1985). Behavior was recorded at 0.8 frames s^{-1} and tapes were viewed at 2.4 frames s^{-1}, a technique previously validated by Arnold-Meeks and McGlone (1986). The 24 h time period was divided into 2 h intervals, resulting in 12 periods.

2.5. Ergonomic measures

Two observers recorded ergonomic measures involved in catching entire litters of piglets from lactating gilts penned in crates or girth tethers. The gilts remained in their housing treatment while these measurements were taken. An experienced farm employee performed the catching maneuvers. The order in which the procedure was performed on the housing treatments was random, in an attempt to equalize any learning that occurred by the employee. One observer recorded the total amount of time required to catch the entire litter. A second observer recorded the number of steps taken by the employee, number of bends at the waist, number of failed attempts at catching piglets and the number of times two (double catch) or three (triple catch) piglets were caught. Our technique was based on the procedures described by Hurst et al. (1989).

2.6. Statistical analysis

Reproductive performance and immune measures were a split-plot design with treatments as the main plot and parity (1 and 2) as subplots. Ergonomic data were collected in only one parity, thus a simple ANOVA with two treatments was used. Behavioral data were analyzed as a split–split plot. Treatments were in the main plots. Parity (1 and 2) was the first subplot while periods (over 24 h) were in the third level of the split–split plot. This analysis requires three error terms (one for the main plot and one each for the two splits). Statistical Analysis Systems Institute Inc. (SAS Insitute Inc.) software was used (SAS Institute Inc., 1988).

3. Results

Reproductive data were collected on 72 crated females and 69 females housed in girth tethers (Table 1). The overall farrowing rate was 82.4% with 141 females farrowing out of 171 bred females. One female farrowed early while still in the gestation facility, because all of the piglets were lost, her data were eliminated from the study. The number of piglets born live and total litter weight did not differ owing to the main effect of housing treatment. However, average piglet

Table 1
Reproductive performance measures (least squares mean ± SE) for gilts housed in crates or girth tethers throughout gestation and lactation and continued on that treatment for a second parity

Measure	Gilts		Sows		*P*-value	
	Crate	Girth tether	Crate	Girth tether	Trt[a]	T×P[b]
Number bred	59	53	29	30	–	–
Number farrowed	46	44	26	25	–	–
Farrowing rate (%[c])	78.0	83.0	89.6	83.3	–	–
Number of pigs born	10.4±0.4	10.8±0.3	10.6±0.5	9.1±0.5	0.20	0.03
Number of pigs born live	9.9±0.4	10.2±0.5	10.4±0.5	8.6±0.5	0.12	0.02
Birth weight (kg)	1.4±0.04	1.5±0.05	1.5±0.04	1.7±0.05	0.001	0.14
Number of stillbirths	0.6±0.16	0.6±0.15	0.2±0.2	0.46±0.2	0.31	0.58
Litter weight, born live (kg)	13.4±0.5	14.8±0.5	15.2±0.7	14.6±0.7	0.54	0.12
Litter weight, born (kg)	14.1±0.5	15.5±0.5	15.8±0.7	15.2±0.8	0.53	0.12
Number weaned	9.0±0.3	8.7±0.3	9.4±0.4	8.1±0.4	0.02	0.14
Litter wean weight (kg)	56.5±1.9	60.5±2.1	54.2±2.5	54.0±2.7	0.41	0.38
Pig wean weight (kg)	6.3±0.2	7.0±0.2	5.8±0.2	6.8±0.2	0.0001	0.38
Mortality (%[d])	10.7±2.0	12.5±2.1	7.6±2.5	7.1±2.7	0.71	0.34
Average feed intake (kg day^{-1})	5.1±0.1	5.0±0.1	5.7±0.2	5.4±0.2	0.09	0.84
Days to rebreed	5.8±0.3	5.8±0.3	5.1±0.9	4.2±0.8	0.64	0.56
Sow weight loss (kg)	15.5±4.5	19.3±3.9	10.9±3.6	15.5±3.4	0.13	0.92

[a]Treatment effect from ANOVA.
[b]Treatment×parity effect from ANOVA.
[c]Not different by chi-squared analysis ($P>0.05$).
[d]Transformed data analyzed, raw least squares means presented.

birth weights were heavier ($P<0.01$) for piglets born in the girth tether system compared with the crate environment. Litter size showed a significant treatment by parity interaction ($P<0.05$). Crated females had an increase in litter size born and litter birth weight from the first to second parity, but females housed in girth tethers had a reduction in litter size born and total litter birth weight from the first to the second parity. Sows housed in the girth tether had 1.5 fewer pigs born per litter in their second parity than litters whose mothers were in the crate. There was a difference ($P<0.05$) owing to treatment in the number of piglets weaned. However, when initial litter size was used as a covariate in the analysis, this effect was no longer significant. Piglet mortality was not influenced by housing treatment (10.7±2% crate and 12.5±2.1% girth tether). Both housing treatments resulted in fewer piglets lost during the second parity compared with the first parity. Piglet weaning weight, was influenced by housing treatment. Piglets that were weaned from females housed in girth tethers were heavier ($P<0.01$) than pigs from crated females. Although pigs from girth tethered sows were heavier,

Table 2
Immune measures for gestating gilts/sows housed in crates or girth tethers

Measure	Gilts		Sows		*P*-values	
	Crate	Girth tether	Crate	Girth tether	Trt[a]	T×P[b]
Natural killer (%)	14.1±0.73	18.5±0.83	26.2±1.4	23.6±1.5	0.68	0.67
SRBC, titer	5.1±0.27	5.5±0.34	6.5±0.36	6.2±0.37	0.88	0.32
Total WBC[d] (number μl^{-1})	11.6±0.65	11.9±0.77	12.5±1.2	14±1.4	0.35	0.54
Lymph.[c] (%)	44.8±2.7	48.3±3.2	54.2±5.1	52.6±5.7	0.78	0.56
Neutrophil (%)	47.9±2.7	44.2±3.2	41.8±5.2	44±5.6	0.80	0.50
Monocyte (%)	3.2±0.35	2.9±0.41	2.6±0.66	2.0±0.72	0.51	0.77
Eosinophil (%)	3.9±0.67	4.5±0.79	1.2±1.3	1.8±1.4	0.51	0.98
Lymph.[c] (number μl^{-1})	5.5±0.43	5.7±0.51	6.5±0.83	7.4±0.90	0.37	0.63
Neutrophil (number μl^{-1})	5.4±0.39	5.2±0.46	5.4±0.75	6.1±0.81	0.51	0.53
Monocyte (number μl^{-1})	0.39±0.05	0.37±0.06	0.31±0.10	0.26±0.11	0.66	0.91
Eosinophil (number μl^{-1})	0.43±0.08	0.56±0.10	0.21±0.16	0.22±0.17	0.51	0.67
Neutrophil: Lymph. (%)	1.5±0.36	1.4±0.42	0.43±0.69	0.63±0.74	0.69	0.78

[a]Treatment effect.
[b]Treatment×parity effect.
[c]Lymph., lymphocytes.
[d]WBC, white blood cells

Table 3
Immune measures for lactating gilts/sows housed in crates or girth tethers

Measure	Gilts		Sows		*P*-values	
	Crate	Girth tether	Crate	Girth tether	Trt[a]	T×P[b]
Natural killer (%)	11.4±0.76	13.9±0.79	33.4±1.8	39.4±1.8	0.45	0.12
SRBC, titer	5.3±0.37	5.4±0.46	5.4±0.49	5.9±0.51	0.42	0.70
Total WBC[d] (number μl^{-1})	13.4±0.92	14.8±1.1	13.0±1.6	11.6±1.9	0.94	0.35
Lymph.[c] (%)	46.7±2.3	45.3±2.6	45.6±4.1	48.4±4.8	0.86	0.56
Neutrophil (%)	49.5±2.5	49.4±2.9	50.8±4.4	48.2±5.2	0.75	0.76
Monocyte (%)	1.5±0.34	2.2±0.39	2.4±0.60	2.5±0.72	0.51	0.63
Eosinophil (%)	2.2±0.47	2.9±0.54	0.94±0.82	0.49±0.98	0.85	0.44
Lymph.[c] (number μl^{-1})	6.3±0.49	7.0±0.56	5.9±0.86	5.7±1.0	0.72	0.57
Neutrophil (number μl^{-1})	6.6±0.69	7.1±0.78	6.6±1.2	5.6±1.4	0.67	0.49
Monocyte (number μl^{-1})	0.16±0.05	0.32±0.05	0.35±0.08	0.31±0.10	0.45	0.19
Eosinophil (number μl^{-1})	0.32±0.07	0.40±0.08	0.12±0.13	0.05±0.15	0.97	0.51
Neutrophil: Lymph. (%)	1.2±0.14	1.3±0.16	1.2±0.25	1.0±3.0	0.96	0.45

[a]Treatment effect.
[b]Treatment×parity effect.
[c]Lymph., lymphocytes.
[d]WBC, white blood cells

Table 4
Probability values for effects ($N=66$ sows) for behavioral data and error mean squares for split–split plot analysis

Effect	Behavior						
	Sitting	Lying	Standing	Feeding	Drinking	Oral/nasal	Total active
Treatment[a]	0.35	0.0004	0.296	0.478	0.002	0.011	0.0004
Error 1[b]	0.0001	0.0001	0.0001	0.534	0.0001	0.0001	0.0001
Parity[c]	0.106	0.0188	0.072	0.371	0.581	0.070	0.011
Treatment × parity	0.130	0.707	0.875	0.520	0.343	0.875	0.707
Error 2[d]	0.079	0.2098	0.0001	0.607	0.045	0.048	0.210
Period[e,f]	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Treatment × period[f]	0.0001	0.0001	0.394	0.999	0.0001	0.002	0.0001
Treatment × parity × period[f]	0.0001	0.170	0.021	0.999	0.237	0.302	0.170
EMS 1[g]	185.7	1230.8	119.4	3.2	19.2	974.2	1230.8
EMS 2	76.8	489.8	154.5	2.7	11.6	577.0	489.8
EMS 3	44.5	364.3	34.4	3.3	6.1	299.7	364.3

[a]Girth tether vs. crate.
[b]Error 1 used to test treatment effect.
[c]Parities 1 and 2.
[d]Error 2 used to test parity and treatment × parity effects.
[e]12 2-hour periods during a 24-h observation.
[f]Residual used to test these effects.
[g]Error mean square for each behavior for each error term.

Table 5
Least squares means for treatment effects on behavior (mean ± SE, min $(2\,h)^{-1}$)

Behavior	Crate	Girth tether
Number of sows	43	33
Stand	1.2 ± 0.48	2.2 ± 0.55
Feed	2.3 ± 0.09	2.3 ± 0.10
Drink	1.7 ± 0.19**	0.73 ± 0.21
Oral/nasal	20.9 ± 1.39*	10.4 ± 1.56
Sit	2.2 ± 0.60	1.1 ± 0.68
Active[a]	28.3 ± 1.58**	16.7 ± 1.78
Lying[b]	91.7 ± 1.58**	103.3 ± 1.78

[a]Active, stand + feed + drink + oral + sit.
[b]Lying, 120-(stand + feed + drink + oral + sit).
*Treatments differ, $P < 0.05$.
**Treatments differ, $P < 0.01$.

Table 6
Ergonomic measures (least squares mean ± SE) for catching pigs in either housing system. All data are averages per ten piglets in each litter

Measure	Crate	Girth tether	*P*-value
Number of litters	13	7	-
Number of bends	10.6 ± 1.0	6.9 ± 1.4	0.05
Number of steps	14.1 ± 1.6	13.3 ± 2.1	0.79
Number failed attempts	0.1 ± 0.1	0.01 ± 0.1	0.49
Number double catches	1.3 ± 0.2	0.7 ± 0.3	0.21
Number triple catches	0.2 ± 0.2	0.8 ± 0.3	0.10
Time required (s)	120.1 ± 17.9	59.6 ± 2.4	0.057

this can be explained by the smaller litter size of tethered females. Average daily feed intake, the number of days required before the sows rebred after weaning and the total amount of weight lost during lactation were not influenced by housing treatment or parity.

Immune data for first parity gilts and second parity sows housed in crates or tethers throughout gestation are shown in Table 2. There were no treatment or treatment × parity effects for all immune measures collected during gestation. Table 3 shows immune data for first parity gilts and second parity sows housed in crates or tethers during farrowing. There were no treatment or treatment × parity effects on immune measures collected during lactation.

P values for the various effects on behavior are shown in Table 4. Lying, drinking, oral/nasal and total active were effected by treatment ($P < 0.05$). Least squares means for treatment effects on behavior are shown in Table 5. Sows in crates spent more time drinking, sitting and engaged in oral/nasal stereotypies ($P < 0.05$) than sows in girth tethers. Overall, sows in crates were more active ($P < 0.01$) than sows in girth tethers. Sows in girth tethers spent more time lying ($P < 0.01$) than sows in crates.

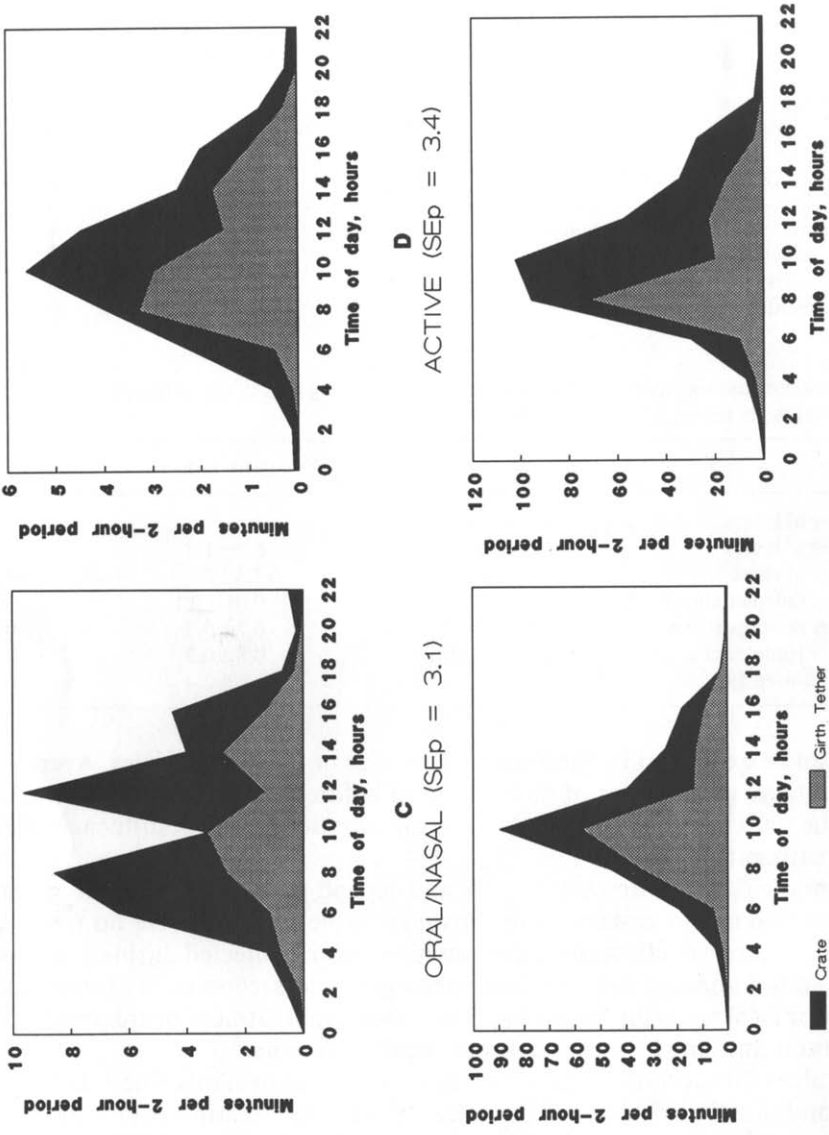

Fig. 1. Plots of behavioral data over time of day for sows in girth tethers or crates during gestation. Fig. 1 (a) is sitting, 1 (b) is drinking or manipulation of the nipple waterer, 1 (c) is oral/nasal stereotypies and 1 (d) is overall activity. Feeding the sows took place at 8 a.m. $N = 66$ sows. SE_p, pooled standard error of the mean.

Table 7
Selected correlations of behavior, immune measures, and reproductive performance

Measure 1	Measure 2	Overall	Number	Within		Within	
				Crate	Number	Tether	Number
Sit	Drink	0.35*	47	0.32	28	0.25	19
Litter weight at birth	Stand	−0.35*	47	−0.30	28	−0.40	19
SRBC titer (farrowing)	Drink	−0.55**	22	−0.49	13	−0.64	9
Number of neutrophils (gestation)	Sit	0.34*	34	0.37	21	0.54	13
Number of lymphocytes (gestation)	Sit	−0.36*	34	−0.37	21	−0.72**	13
NK cytotoxicity (gestation)	Litter weight at wean	−0.41*	28	−0.35	17	−0.49	11
SRBC titer (farrowing)	Litter weight at birth	0.52*	22	0.47	14	0.62	9
Average daily sow feed intake (farrowing)	NK cytotoxicity (farrowing)	0.56*	20	0.64	9	0.58	11
Average daily sow feed intake (farrowing)	SRBC titer (gestation)	0.78***	15	0.87*	7	0.54	8
WBC (gestation)	SRBC titer (gestation)	0.53*	20	0.48	12	0.60	8

*$P<0.05$.
**$P<0.01$.
***$P<0.001$.

Parity had an effect ($P<0.02$) on lying behavior and total active behavior. A significant ($P<0.01$) period (time of day) effect for all behaviors exists. There were no significant ($P>0.10$) treatment×parity effects. Treatment×period effects were highly significant ($P<0.01$) for sitting, lying, drinking, oral/nasal and active behaviors, but not significant ($P>0.10$) for standing and feeding behaviors.

For most behavioral measures, both the treatment effect and treatment×period (time of day) interaction were significant (Table 4). Examination of the figures (Fig. 1) shows that during certain times of day gilts/sows were inactive, while during active periods, pregnant females in crates showed elevated activity. Over the 24 h period and particularly in certain periods, sows in crates spent more minutes sitting than sows in girth tethers (Fig. 1(a), $P<0.05$). Drinking behavior was higher ($P<0.02$; Fig. 1(b)) among crated sows than girth tethered sows. Oral/nasal behavior was higher ($P<0.01$) in sows housed in crates than girth tethers (Fig. 1(c)). Overall, sows in crates were more active ($P<0.01$) than sows in girth tethers (Fig. 1(d)).

Table 6 indicates the time and effort required by an employee to catch a litter of piglets (adjusted to an average litter size of ten piglets). More bends at the waist were performed by the employee when catching piglets from a farrowing crate than when catching piglets in a girth tether farrowing facility, (10.6 ± 1.0 bends vs 6.9 ± 1.4 bends, crate vs girth tether, respectively). In addition, more time was required to gather all the piglets in the crate compared with piglets in the girth tether facility (120.1 ± 17.9 s vs 59.6 ± 2.4 s, crate vs girth tether, respectively).

Correlations were calculated among all measures to generate hypotheses to be tested in future studies. In Table 7 selected correlations (overall and within-treatment correlations) are presented that were significant in terms of statistics and perhaps pig biology. Sows that spent more time sitting tended to spend more time drinking ($r=0.35$), had a greater number of circulating neutrophils ($r=0.34$) and fewer circulating lymphocytes ($r=-0.36$). Sows that were more active and therefore spent more time standing had lighter litter weights at birth ($r=-0.35$). Sows with heavier litter weaning weights tended to have lower NK activity ($r=-0.41$) and greater SRBC titer ($r=0.52$). Sows that ate more feed in lactation also had greater titer to SRBC in gestation ($r=0.78$) and greater NK activity ($r=0.56$).

4. Discussion

The overall farrowing rate of 82.4% was well within industry standards for US herds. As an example, a recent survey of breeding herd performance showed the average farrowing rate for 382 herds, totaling over 170 000 sows, averaged 77.2%, while the top one-third of farms averaged a 83% farrowing rate (Pig Improvement Company, 1993). Considering the two-parities, crated sows had a 81.8% farrowing rate (from 88 matings) and females in the girth tether had 83.1% farrowing rate (from 83 matings). Most of the previous studies that evaluated teth-

ers compared the neck tether to other systems and found similar farrowing rates for sows in neck tethers, gestation crates or pens (Jensen et al., 1970; Friend et al., 1988; McGlone et al., 1988).

Our data show a clear reduction in numbers of piglets born in the second parity for the girth tether system compared with the crated system (Table 1). The lower litter size born led to a reduced number of piglets weaned, although piglet birth-to-weaning mortality was similar for the two systems. A past study (McGlone et al., 1988) which examined neck tethers, gestation crates and other systems showed that sows in neck tethers during gestation, had 8.9 pigs born live and crated sows had 10.5 pigs born live per sow. While this difference was not significant (owing to large variation) in the past study, the direction of the difference supported the idea that tethering reduces litter size.

The statistically significant, but small increase in piglet birth weight was expected since fewer piglets were present in utero. However, because the stillbirth rate was not affected by treatments in Parity 2 (Table 1), it is possible that the girth tether system caused either a reduced ovulation rate or a reduced early embryonic survival. Reduced ovulation or embryonic survival is consistent with the hypothesis that girth tethered sows experience stress (reviewed by Varley, 1991). In addition, with 1.5 fewer pigs born per litter and 1.3 fewer pigs weaned, the girth tether environment is undesirable from an economic standpoint.

The reduced litter size for girth tethered sows compared with crated sows was reported previously by Den Hartog et al. (1993) in a large-scale field trial in The Netherlands involving 2840 litters. In addition, Hartog et al. reported a greater sow replacement rate for girth tethered sows compared with crated sows. Their study involved a 4 year period, but our data were not collected over enough parities to obtain an accurate measure of sow replacement rate. However, our data on gilt and sow immune function, including measures of both the cellular and humoral arms of the immune system, did not indicate any signs of immunosuppression.

The lack of an effect of housing systems on the immune system may indicate several directions for future work. First, the physiological mechanisms of stress that might have caused suppressed litter size among sows, did not cause an effect on WBC distribution, antibody response or NK cell cytotoxicity. Second, it is known from past work (for example, McGlone et al., 1993) that stress has significant effects on porcine WBC distributions and NK activity. Therefore, either (a) these reproductive or immune measures respond independently to stressors or (b) certain stressors influence only certain measures of immunity.

Blood glucocorticoid status in these animals was not measured for two reasons. First, the tether environment is known to elevate glucocorticoids in an acute and sometimes chronic manner (Barnett et al., 1985, 1987a,b, 1988; Becker et al., 1985; Friend et al., 1988). Second, we are presently operating under the model that animal welfare is compromised when animals enter the prepathological state (Moberg, 1985; McGlone, 1993), regardless of the status of intermediate hormone mediators. This model holds that if the immune or reproductive systems

are suppressed, animal welfare is compromised. Based on these criteria, sows in the girth tether system have compromised welfare.

The behavioral measures showed striking effects of housing systems on behavior. Sows in the gestation crate were more active overall and showed elevated drinking (or playing with the waterer), sitting and oral/nasal stereotypies. The various forms of oral/nasal stereotypies (bar chewing, trough rubbing, sham chewing) were not separated, but it was clear that crated sows showed much more oral/nasal stereotypies. The majority of the extra time spent in stereotypies was spent biting the bars, but the girth tethered sows did not have a bar in front of them to bite, chew or rub, nor did they increase the time spent manipulating the trough or side division bars. To our knowledge, this work is the first to report elevated stereotypies in crated compared with tethered sows. Den Hartog et al. (1993) did not find an elevation in bar biting in girth tethered sows compared with crated sows. Perhaps the round, metal, horizontal bars in the front of the crate in this experiment encouraged bar biting. It is interesting that this elevated bar biting was associated with enhanced reproduction compared with tethered sows that showed less stereotypies and reduced litter size. Cronin (1985) and Dantzer (1986) suggested that stereotyped behavior may serve as a coping mechanism, enabling the sow to successfully cope with aggression or conflict induced by the environment. Wiepkema et al. (1987) found that veal calves that showed stereotyped tongue playing had fewer abomasal ulcers compared with calves that did not show stereotyped behavior. Our data support the idea that expression of more oral/nasal stereotypies is beneficial. The girth tether system is undesirable from a welfare and economic standpoint, and use should be discouraged on commercial farms. In sharp contrast, sows in the gestation crate system showed no evidence of stress and expression of large amounts of oral/nasal stereotypies were associated with enhanced litter size.

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