CORTISOL RESPONSE OF GILTS IN TETHER STALLS


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Summary

Several experiments were conducted to evaluate serum cortisol concentrations and the circadian rhythm of this hormone in gilts tethered in stalls. Control animals were penned individually. In the initial experiment, 18 nongravid gilts were placed in tether stalls after being in either tether stalls or individual pens for 2 wk. No significant differences were found in serum cortisol concentrations. In a second experiment, 16 ovariectomized gilts were placed in tether stalls or individual pens for up to 5 wk. Estrus was induced during wk 3 and 4. During the first day in tether stalls, serum cortisol concentrations increased (P<.05) and the circadian rhythm of cortisol was disrupted for 4 d. During estrus, the circadian rhythm of cortisol was interrupted for several days in the gilts, regardless of housing. After 4 wk, morning concentrations of cortisol were higher for gilts in tether stalls. The results indicate that: 1) the initial response to tethering varies according to previous penning and handling experience, 2) although the circadian rhythm of cortisol was either altered or disrupted during estrus, such disruptions were not influenced by type of penning and 3) tether stalls may chronically increase cortisol concentrations in gilts.

(Key Words: Tethers, Cortisol, Circadian Rhythm, Housing, Estrus, Gilts.)

Introduction

Restraint of swine by tether stalls has been a system chosen for its low investment, minimum use of floor space and equipment, and ease of maintenance and of monitoring animals (Robson, 1966). However, restraint by tethers has been listed by some as a practice that may cause stress or suffering (Fox, 1980; Fraser and Fox, 1983). Previous researchers have investigated possible adverse effects on reproduction and production performance in such systems, but results were inconclusive. England and Spur (1969) found that restriction by stalls resulted in lower mating rates and irregular estrous expression, although no differences were observed in the number of pigs farrowed and birth weights. Jensen et al. (1970) found that in some experiments, tethered gilts had heavier adrenal weights and suggested that tethering produced a stress with respect to sexual development and onset of puberty but did not affect farrowing performance. Over a 3-yr period, Teodorovic (1978) found no production differences between tethered vs grouped sows.

Our experiments were designed to investigate whether tether stalls influenced serum cortisol concentrations. Changes in serum cortisol, the predominant glucocorticoid in swine, are considered a valid indicator for stress in this species (Dantzer and Mormède, 1981; Moss, 1981; Stott, 1981). The first experiment...
evaluated the novelty of being penned in tether stalls. A second experiment assessed not only the immediate effect of being placed in tether stalls, but also the effect on the animal in estrus and the possible long-term (weeks) consequences.

Materials and Methods

Exp. 1

Eighteen crossbred (Yorkshire × Landrace) gilts, approximately 10 mo of age, which had been housed in groups of 15 to 20 in a swine building, were randomly divided into three groups of six gilts. For the first 2 wk, Group I was tethered (girth) in stalls, while Group II and Group III were individually penned in 2.4 × 1.8 m pens. Stalls were 63.5 cm wide with side panels 96.5 cm long. A girth tether attached to a 33.0-cm chain was bolted to the floor. Animals were fed 1.8 kg of a corn-soybean meal growing diet at 0700 h. Lights were on continuously for filming of behavioral activities to be reported elsewhere. All penning arrangements were in the same room of an enclosed swine barn. At the end of 2 wk, gilts were removed from pens and indwelling jugular catheters were implanted (Ford and Maurer, 1978). Gilts were returned to the same pens and allowed 3 d to recover, during which they were accustomed to the sampling procedure. At 0700 h on d 1 of the experimental period (4 d after catheters were implanted), Group I was moved into a second set of tether stalls, Group II into tether stalls and Group III into another set of individual pens (2.4 × 1.8 m). Blood samples were collected at .5, 1, 2, 4, 6, 8, 12, 24, 36, 48 and 60 h after moving. Five milliliters of blood were drawn and immediately placed on ice. Serum was obtained by centrifugation at 2,000 × g and frozen until analysis of cortisol concentrations were determined by radioimmunoassay. The cortisol radioimmunoassay was validated for porcine serum extracted with ethanol. A dose response curve for two pooled porcine serum samples was parallel to the cortisol standard curve. The cross-reactivity of the antibody, at 50% displacement, was reported by the manufacturer as: cortisol, 100%; compound S, 10%; corticosterone, 4%; 17α-hydroxyprogesterone, 11.4% and deoxycorticosterone, 2.4%. Sensitivity of the assay was 20 pg/tube and extraction efficiency averaged 85%. The accuracy of the assay was determined by adding a known amount of cortisol to pooled adrenal-suppressed boar serum. Intrassay and interassay coefficient of variations were 16.1 and 7.0%, respectively. Data were statistically analyzed as a split-plot in time with repeated measurements on the same animal (Gill and Hafs, 1971).

Exp. 2

Sixteen crossbred (Landrace × Yorkshire) gilts, 18 mo old, were individually penned (2.4 × 1.8 m) in an enclosed swine building. Lights were on from 0600 to 2000 h. Each gilt had an indwelling jugular catheter. Animals were fed 1.6 kg of a corn-soybean meal growing diet at 1100 h. In order to document the 24-h rhythm of cortisol concentrations, blood samples were collected hourly for 24 h, beginning at 1300 h on the day of the experiment.

Exp. 3

Sixteen crossbred (Landrace × Yorkshire) gilts, 15 to 16 mo old, were used for Exp. 3. All animals were ovarioctomized and had participated in an experiment that evaluated estrous behavior after treatment with exogenous estrogen 1 mo before the beginning of this experiment. Prior penning had been in groups. Lighting and feeding schedules, blood collection and processing and determination of serum cortisol concentrations were the same as in Exp. 1.

Period 1 (7 d). On d 1, indwelling jugular catheters were implanted and gilts were transferred and housed in individual pens (2.4 × 1.8 m). Blood samples (5 ml) were collected at 0700 and 1900 h for 7 d starting the evening of cannulation. These time periods were chosen as indicators of the peak (AM) and trough (PM) of the circadian rhythm of serum cortisol concentrations as determined in Exp. 2.

Period 2 (9 d). Gilts were randomly divided into four groups of four gilts each. At 0730 h on d 1 of Period 2, Groups I and II were moved into tether stalls (same as Exp. 2), while Groups III and IV were moved into a different set of individual pens (2.4 × 1.8 m). Five milliliters of blood were collected at .5, 1, 2, 4, 6, 8 h after placement and, for 9-d samples, were collected at 0700 and 1900 h, inclusive of d 1.

Periods 3 and 4 (1 wk Each). On the first day at 0730 h of Period 3, Group I in tether stalls and Group III in individual pens received, im 1.5 mg estradiol benzoate in 1 ml of sunflower seed oil and Group II in tether stalls and
Group IV in individual pens received 1 ml of sunflower seed oil im. During Period 4, Groups II and IV received estradiol benzoate and Groups I and III received sunflower seed oil. Five milliliters of blood were collected at 0700 and 1900 h daily for 7 d in each period. Estrous response was determined by exposure to two boars at 1300 h. Boars were brought into the room for approximately .5 h daily and freely moved up and down the alley between the pens while gilts remained in their respective pens and were tested for response by back pressure. Blood samples were collected 15 min (1300 h) after the boars were introduced.

**Period 5.** Gilts were maintained in their respective pens. Blood samples were collected for 5 d at 0700 and 1900 h.

Data were grouped for analysis as follows: 1) Period 1; 2) Period 2—d 1; 3) Period 2—AM and PM for d 9; 4) Periods 3 and 4; 5) Periods 3 and 4—1300 h; 6) Period 5. Each division was analyzed as a split-plot in time with repeated measurements on the same animal (Gill and Hafs, 1971). Period 5 data were analyzed according to treatment effects of wk 3 and 4 to test for carry-over effect of injections.

**Results**

**Exp. 1.** Serum cortisol concentrations for Groups I, II and III for 60 h after being moved are listed in Table 1. Concentrations in Group II (recently tethered) at .5, 1 and 2 h appeared elevated in comparison with Groups I (adapted to tethers) and III (individually penned); however, over the 60-h sampling period, the analysis of variance resulted in no significant differences associated with treatment.

**Exp. 2.** Variations in serum cortisol concentrations within a 24-h sampling period are shown in Figure 1. The peak concentrations of 16 ng/ml or higher extended from 0300 to 1300 h.

**Exp. 3.** Mean serum cortisol concentrations for Period 1 while all pigs were individually penned are listed in Table 2. The effect of cannulation resulted in high (43.4 ± 2.4 ng/ml) cortisol concentrations for the PM (1900 h) concentration on d 1 and the following AM (0700 h; 22.2 ± 2.4 ng/ml) concentration on d 2. Concentrations for the last 5 d (d 3 to 7) were higher (P<.01) in the AM than in the PM (14.8 ± 1.1 vs 6.5 ± 1.0 ng/ml).

Serum cortisol concentrations for 11.5 h after gilts had been placed in either tether stalls or individual pens are included in Figure 2. Before moving into different pens (–.5 h), serum cortisol concentrations were similar. By .5 h after moving, serum cortisol concentrations for gilts in tether stalls had increased 152% over those in individual pens and remained elevated 90% at 11.5 h. Also illustrated in Figure 2 are

### Table 1. Serum Cortisol Concentrations (ng/ml) in Group Ib, Iic and Iidd Gilts for 60 Hours After Placement in Respective Pens in Experiment I

<table>
<thead>
<tr>
<th>Hours after placement</th>
<th>Tethered</th>
<th>Individual pens</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group I</td>
<td>Group II</td>
</tr>
<tr>
<td>.5</td>
<td>21.1 ± 5.5</td>
<td>46.0 ± 5.5</td>
</tr>
<tr>
<td>1</td>
<td>22.4 ± 5.5</td>
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<td>2</td>
<td>21.8 ± 5.5</td>
<td>36.7 ± 5.5</td>
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<tr>
<td>4</td>
<td>23.6 ± 5.5</td>
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<td>6</td>
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<td>12</td>
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<td>18.8 ± 6.0</td>
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<td>29.7 ± 5.5</td>
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<td>48</td>
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</tr>
<tr>
<td>60</td>
<td>23.4 ± 5.5</td>
<td>23.0 ± 5.5</td>
</tr>
</tbody>
</table>

*Least-squares means ± SE.

b Group I gilts were housed in tether stalls for 2 wk before placement in another set of tether stalls.

c Group II gilts were individually penned for 2 wk before placement in tether stalls.

d Group III gilts were individually penned for 2 wk before placement in another set of individual pens.
the mean AM and PM serum cortisol concentrations for 9 d after gilts had been placed in either tether stalls or individual pens. For the first 4 d, the rhythm in the tethered pigs is dissociated and clearly contrasts with the established rhythm of the individually penned pigs. On d 5, the rhythmicity returns in the tethered gilts, with both tethered and individually penned pigs demonstrating higher concentrations of cortisol in the AM than in the PM.

Serum cortisol concentrations in gilts injected with estradiol benzoate or sunflower seed oil are illustrated in figure 3. All gilts injected with estradiol benzoate were in estrus on d 4 and 5 as determined by boar exposure. Serum cortisol concentrations were higher (P<.01) in gilts injected with estradiol benzoate than in gilts given sunflower seed oil, regardless of whether gilts were housed in tether stalls or in individual pens (P>.05). For gilts in estrus, disruption of the rhythm occurred on d 2 through 6 (figure 3). After 15 min of exposure to boars on d 3, 4, 5 and 6, higher (P<.0001) cortisol concentrations were found in estrous gilts and did not differ (P>.05) between gilts housed in tether stalls and individual pens (figure 4). During Period 5, 4 wk after being placed in respective pens, gilts in tether stalls had higher (P<.01) mean AM concentrations (24.5 ± 1.5 ng/ml) than those in individual pens (16.9 ± 1.5 ng/ml). Mean PM concentrations were similar (11.3 ± 1.6 vs 11.1 ± 1.6 ng/ml). Statistical analysis revealed no residual effect of treatments during wk 3 and 4 on concentrations during wk 5.

**Discussion**

The immediate changes in serum cortisol concentrations associated with penning of gilts in tether stalls vary. In the first experiment, no significant change was found in cortisol concentrations in gilts that were placed in tether stalls for the first time or for a second time after having been previously tethered for 2 wk. A response by gilts tethered for the first time was suggested by higher cortisol concentrations within the first few hours; however, animal variability was extreme because measurement of areas under the individual animal response curve for the first 12 h revealed a sixfold difference among pigs. Similarly, the data at 24 h suggested that tethering may disrupt or alter the circadian rhythm of cortisol. The gilts in this experiment had been group penned with human interaction limited to feeding and health management; thus, such variation in response may be confounded with the novelty of interactions with humans. In another experiment

<table>
<thead>
<tr>
<th>Day</th>
<th>AM</th>
<th>PM</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>22.2 ± 2.4</td>
<td>43.4 ± 2.4</td>
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<tr>
<td>2</td>
<td>14.6 ± 2.4</td>
<td>5.7 ± 2.4</td>
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<td>3</td>
<td>16.8 ± 2.6</td>
<td>3.8 ± 2.6</td>
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<tr>
<td>4</td>
<td>15.5 ± 2.6</td>
<td>6.5 ± 2.6</td>
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</tr>
<tr>
<td>6</td>
<td>14.8 ± 2.4</td>
<td>10.9 ± 2.4</td>
</tr>
<tr>
<td>7</td>
<td>14.8 ± 2.4</td>
<td>5.2 ± 2.4</td>
</tr>
</tbody>
</table>

*Gilts were housed in individual pens.*

*b Least-squares mean ± SE.
Figure 2. Serum cortisol concentrations (mean ± SE) in gilts moved into tether stalls or individual pens on d 1 of Period 2 of Exp. 3 and at daily AM and PM collection times for 9 d thereafter.

Figure 3. AM and PM serum cortisol concentrations (mean ± SE) in gilts housed in tether stalls or individual pens and injected with either estradiol benzoate (EB) to induce estrus or with sunflower seed oil (SFO) as the control vehicle during Periods 3 and 4 of Exp. 3.

Figure 4. Serum cortisol concentrations (mean ± SE) in gilts injected with either estradiol benzoate (EB) or with sunflower seed oil (SFO) after 15 min boar exposure during Periods 3 and 4 of Exp. 3.
cortisol was disrupted for 4 d after placement in tether stalls. Circadian rhythmicity of the adrenal gland and its response to various stressors has been characterized by several researchers (Zimmerman and Critchlow, 1967; Ader and Friedman, 1968; Dunn et al., 1972; Seggie and Brown, 1975); however, most of these were within 24 h after exposure. In rabbits, first exposure to immobilization stress resulted in disrupted rhythmicity; however, after 7 d of repeated immobilization the rhythm was not altered (Kawakami et al., 1972). In pigs, Barnett et al. (1981a) reported a disruption of circadian rhythm of cortisol for 4 d when pigs were moved to group pens after being individually penned for 9 wk. Similarly, our results suggest that placement in tether stalls initially disrupts the circadian rhythm, but reassociation occurs by at least d 4. Thirdly, the circadian rhythm of cortisol concentration was interrupted for several days for gilts in estrus. Alterations of the rhythm have been reported in mice at different ages, with responses varying with age and reproductive status (Paris and Ramaley, 1974). The authors hypothesized that the adrenal gland influenced fertility, most likely via the pituitary. Jensen et al. (1970) suggested that the increased adrenal activity in tethered gilts may be associated with reproductive problems, including silent estrus and infantile tracts as a result of tethering. However, our results also showed serum cortisol concentrations increased during estrus regardless of whether gilts were in tether stalls or individual pens. The increase in glucocorticoids associated with estrus has been reported in mice (Pollard et al., 1975; Nichols and Chevins, 1981) and in swine (R. K. Christenson, personal communication). Similarly, type of penning had neither an influence on the gilts response to boars, nor on estrous duration and intensity. Although serum cortisol concentration in the estrous gilts were higher 15 min after boar exposure than in the nonestrous gilts, close examination of the data reveals that this increase is really the increase associated with induced estrus and was not related to the presence of the boar. And finally, after 4 wk, higher AM concentrations of cortisol were found in gilts tethered than in those individually penned; however, PM concentrations were similar. Because the morning is the time of greater activity for swine, the physical restriction by tethers during this time may account for the higher AM concentrations.

In conclusion, the initial response of gilts to being placed in tether stalls appears to be influenced by the animals' previous handling and housing experience. Tethering may result in an increase in cortisol on the first day and disrupt the circadian rhythm of this hormone for up to 4 d. The circadian rhythm of cortisol in gilts penned in tether stalls for several weeks appears altered, with higher AM concentrations in gilts in tether stalls than in those in individual pens. Tethering does not appear to interfere with cortisol secretions that occur during estrus, nor with the behavioral expression (in response to boars) of this state.

**Literature Cited**


