INTRAUTERINE POSITION EFFECTS IN MALE AND FEMALE SWINE: SUBSEQUENT SURVIVABILITY, GROWTH RATE, MORPHOLOGY AND SEMEN CHARACTERISTICS[1,2]

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ABSTRACT

Pigs of known intrauterine position were obtained from 31 litters by a procedure in which donor sows were slaughtered at d 112 of gestation, their uteri removed and piglets delivered manually. Uterine position was recorded for each piglet as being positioned between two female fetuses (OM), between a male and female fetus (1M), between two male fetuses (2M), between a female fetus and the tip of the uterine horn (0E) or between a male fetus and the tip of the horn (1E). Piglets were fostered as litter groups to recipient sows and reared in these groups until 120 d of age. They then were regrouped and housed as groups of three and six for males and females, respectively. Intrauterine position had no effect on birth weight or survivability of pigs of either sex, although pigs positioned in utero nearest the ovaries (0E and 1E) tended to be heavier at birth. Body weights were similar among groups in each sex at 120 and 175 d of age when given ad libitum access to feed; however, 2M males gained more weight from d 175 to 270 under restricted feeding conditions ($P < .05$). Intrauterine position had no effect on anogenital distances either at birth or 120 d of age, and predicted testes weights were similar among males from different positions. Semen characteristics at 220 d of age did not appear to vary due to prenatal environment. Although volume tended to be less for 0M males ($P < .12$), concentration, motility and sperm/ejaculate were similar among groups. Sperm abnormalities were more frequent among 2M boars ($P < .05$); however, this effect was due to a single boar. Thus, intrauterine position had little effect on subsequent survivability or phenotypic characteristics of swine; however, in a competitive environment (limited feed), males that developed between other males in utero may have an advantage.

(Key Words: Uterus, Pigs, Growth, Testes, Semen Characters.)

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Introduction

The presence of androgens at critical periods of development is believed to be responsible for mammalian sexual dimorphism (Jost et al., 1973); however, sources of variation within the sexes remain largely undefined. In rats and mice, the sex of adjacent fetuses in utero influences within-sex variation in anogenital distance (Clemens, 1974; Gandelman et al., 1977; vom Saal and Bronson,

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1978; vom Saal, 1981) and several reproductive traits (vom Saal and Bronson, 1980a; vom Saal et al., 1981, 1983; Kinsley et al., 1986a). This "intrauterine position phenomenon" has been correlated with prenatal hormone concentrations (vom Saal and Bronson, 1980b; vom Saal et al., 1983). Similarly, androgen administration to genotypic females during sexual differentiation results in phenotypic masculinization (Gandelman et al., 1979; DeHaan et al., 1987; Hamernik et al., 1987) and enhanced growth rates (Swanson and Van der Werff ten Bosch, 1963; Beatty et al., 1970; Tarttelin et al., 1975; Jansson et al., 1985; Jenkins et al., 1988) in several species.

Because swine also are born in litters, variation in performance might be influenced by sex of adjacent siblings in utero. As in rodents, in swine the male has higher prenatal concentrations of testosterone than the female does (Stewart and Raeside, 1976; Ford et al., 1980). Thus, the objective of this study was to determine whether intrauterine position, relative to the sex of adjacent littermates, affects subsequent performance and phenotypic characteristics of swine.

Materials and Methods

Animals. Pigs of known intrauterine position were obtained by a procedure in which donor sows were slaughtered at d 112 of gestation and the uteri removed. Piglets were delivered by manually rupturing the uteri. Intrauterine position was recorded for each piglet relative to the sex of adjacent littermates. Intrauterine position was recorded as between two female fetuses (**0M**), between a male and female fetus (**1M**), between two male fetuses (**2M**), between a female fetus and the tip of the uterine horn (**0E**) or between a male fetus and the tip of the horn (**1E**). No fully formed pigs were found dead in the uterus at recovery. Intrauterine position of fetuses located at the cervix also were recorded in this manner. In addition, piglets were classified according to absolute uterine position, either at the tip of the uterine horn, in the central zone of the horns or at the cervix.

Piglets were fostered as litter groups to recipient sows that had been induced to farrow on the same day and whose own piglets had been removed. In order to standardize rearing environments, the size of experimental litters with fewer than 10 pigs was adjusted to this level by addition of nonexperimental piglets from the recipient sow's original litter. Experimental pigs were obtained in this manner from 31 litters from four farrowing groups (February, March, July and August 1986). Litters in each group were born within a 5-d period.

Pigs were reared primarily as litter groups from weaning until 120 d of age, with efforts made to ensure that both sexes were represented in all rearing groups. Pigs were regrouped at 120 d of age and maintained thereafter in unisexual groups of six and three animals/pen for gilts and boars, respectively. Animal were allotted to pens on the bases of uterine position, BW and litter, such that uterine position and litter effects were balanced across pens and weight variation within pens was minimized. Thus, whenever possible, 2M, 1M and 0M individuals of similar size were present in each pen. A total of 78 females (n = 16, 26, 17, 12 and 7 for 0M, 1M, 2M, 1E and 0E positions, respectively) and 77 males (n = 13, 24, 22, 7 and 11 for 0M, 1M, 2M, 1E and 0E positions respectively) were allotted by this procedure. Due to the larger numbers of 1M pigs, some pigs in this group were dropped from the study at 120 d.

Housing. Piglets were housed from d 28 to 56 in 1.2 × 1.2-m nursery pens with a space allowance of .18 m^2/pig (eight pigs/pen). During the grower phase (d 56 to 120) pens were 2.1 × 3.0 m, giving a space allowance of .79 m^2/pig (eight pigs/pen). From 120 to 270 d of age, both boars and gilts had access to 3.0 m^2/pig, with boars housed in 1.5 × 6.1-m pens and gilts in 3.0 × 6.1-m pens.

Performance. Data on piglet weight at birth and mortality through weaning (28 d) were collected on all pigs in the study. Pigs had ad libitum access to feed from weaning until 175 d of age and were limit-fed thereafter. All diets were formulated according to NRC requirements for swine. Diets fed during the nursery, growing and finishing phases were corn-soybean based and contained 18, 16 and 14% CP respectively. During limited feeding, pigs were fed 2.2 kg/(pig·d) of a 14% CP corn-soybean-alfalfa based diet in a single meal from the floor. Pigs were weighed at 120, 175 and 270 d of age in order to determine whether uterine environment, relative to the sex of adjacent fetuses, affected subsequent growth rate.

Phenotypic Characteristics. Body measurements included anogenital distance for both sexes and testicular measurements and semen evaluation for males. Anogenital distance was the distance between the center of the anus and the ventral tip of the vulva in females and between the center of the anus and the opening of the prepuce in males. Anogenital distance was measured at birth and again at 120 d of age in both sexes. Testicular length and total width of the two testes were measured in boars at 140 and 160 d of age, and testis weight was predicted from these two sets of measurements using the procedure of Schinckel et al. (1984).

A single semen collection was made from each boar at approximately 220 d of age. Boars previously had been exposed to and allowed to copulate with receptive gilts and were provided approximately 1 wk of sexual rest before collection. Following collection, total ejaculate volume was recorded. Semen was strained to remove gelatinous material and strained volume was recorded. Samples were assessed for sperm motility; concentrations and total sperm/ejaculate were estimated by hemocytometry techniques. Proportions of morphological sperm abnormalities were determined after staining.

Statistical Analysis. Continuous dependent variables were analyzed using least squares analysis of variance (SAS, 1982) with separate analyses applied to males and females. The general model included effects of farrowing group, litter nested within farrowing group and intrauterine position as independent variables. Weight at birth, 120 d and 175 d of age were analyzed in this manner with litter size included as a covariate for evaluation of differences in birth weight. For analysis of weight gain while on limited feed (d 175 to 270), pen effects also were included as an independent variable. Anogenital distances and predicted testes weight were analyzed using the general model with BW at the time of measurement fitted as a covariate. Semen characteristics were analyzed using the general model with testicular dimensions and BW included as covariates. Data on sperm motility and proportion of abnormalities were transformed (log) prior to analysis to achieve homogeneity of variance. The effect of absolute uterine position on birth weight was evaluated using a model that included farrowing group and litter nested within farrowing group. Chi-square techniques were used to determine differences in survival at 3 and 28 d of age attributable to intrauterine position.

Results

The slaughter procedure for manually delivering piglets generally was successful, with 243 of 261 piglets surviving to 3 d of age. Litter size ranged from 2 to 13 piglets and averaged 8.4 piglets/litter.

Sex of adjacent fetuses did not significantly affect birth weight in either males or females (Table 1). Pigs in positions nearest the ovaries (0E and 1E) had numerically greater weights at birth in both males and females (tip of horn, 1.41 kg; central zone, 1.26 kg; at cervix, 1.26 kg). Pigs in these positions also tended to have greater survival rates at both 3 and 28 d of age (Table 2). When data for males and females were combined, pigs positioned at the tips of the horns averaged 86% survival at 3 d of age compared with 81% for pigs located more caudally, and 81% compared with 73% survival at weaning. The increased survival rate may be associated with the greater birth weights of pigs from these positions. Average birth weight of males was 5.5% greater than that of females (1.36 and 1.23 kg, respectively), a difference of approximately twice that reported by Bereskin et al., (1973). Survival rates among males and females were similar.

No effects of intrauterine position were found on BW at 120 or 175 d of age (Table 1), both weights reflecting growth under an ad libitum feeding schedule. Intrauterine position did, however, affect weight gain when pigs were limit-fed (d 175 to 270). When feed was restricted, males that had been positioned in utero between other male fetuses (2M) had greater ($P < .05$) weight gains than males that had been positioned between females in utero (0M). Among females, weight gain under limited feeding was less for 0M females; however, this difference was not significant, and 2M females displayed no advantage such as that shown by their male counterparts.

Intrauterine position had no discernible effect on anogenital distance at birth or at 120 d of age in either sex (Table 3). Likewise, intrauterine position did not affect predicted testes weight of males. Means for predicted testes weights ranged from 387 g for 2M boars to 422 g for 1M boars.

Table 4 shows semen characteristics. Total semen volume tended ($P < .12$) to be less for 0M boars; volumes were similar among pigs from other positions. This trend also was seen in the strained semen volume ($P < .10$). Sperm

TABLE 1. LEAST SQUARES MEANS FOR SUBSEQUENT GROWTH RATES OF PIGS FROM DIFFERENT INTRAUTERINE POSITIONS DURING PRENATAL DEVELOPMENT[a]

Item	Intrauterine position[b] OE	OM	1M	2M	1E	SD[c]	Signif.
No. of pigs							
Males	15	14	52	36	14		
Females	12	21	45	18	16		
Birth wt, kg							
Males	1.38	1.37	1.38	1.27	1.44	.20	NS[f]
Females	1.36	1.24	1.26	1.25	1.36	.19	NS
No. of pigs							
Males	11	13	30	23	11		
Females	10	16	31	17	14		
120-d wt, kg[d]							
Males	59.6	54.8	64.7	60.6	57.2	7.9	.09
Females	57.7	57.6	58.5	58.3	56.3	6.4	NS
175-d wt, kg[d]							
Males	109.8	104.7	104.5	102.9	101.6	9.6	NS
Females	99.5	98.6	99.8	99.4	96.7	7.8	NS
No. of pigs[e]							
Males	11	13	24	22	7		
Females	7	16	26	17	12		
Gain: d 175-270 kg[e]							
Males	31.1	25.1	36.9	41.1	21.5	8.8	.05
Females	10.3	28.9	35.9	32.7	42.6	11.0	NS

[a]All means adjusted for effects of farrowing group and litter. Means for birth weight also adjusted for litter size.

[b]Intrauterine position defined as prenatal development between: two female fetuses (OM), two male fetuses (2M), a male and a female fetus (1M), a female fetus and the tip of the uterine horn (OE), a male fetus and the tip of the horn (1E).

[c]Standard deviation.

[d]Ad libitum feeding schedule.

[e]Limited feeding schedule (2.2 kg/(pig d). Data available from three farrowing groups only.

[f]NS = not significant.

concentrations were highest in 0M and 2M boars, but differences were not statistically significant. As a consequence of the slightly higher concentration and volume, total sperm/ejaculate was numerically greatest for 2M boars. Sperm motility tended to be greater in boars that has been positioned in utero next to females (0M and 0E) and overall averaged 76%. Sperm abnormalities were greater in 2M boars than in boars from the other positions ($P < .05$); however, this effect can be attributed to the influence of a single boar in which 37.5%

TABLE 2. SURVIVAL RATES FOR PIGS FROM DIFFERENT INTRAUTERINE POSITIONS DURING PRENATAL DEVELOPMENT[a]

Sex and age	Intrauterine position 0E	0M	1M	2M	1E
Males					
Age: 3 d	.73	.88	.76	.76	1.0
Age: 28 d[b]	.73	.88	.72	.61	.83
Females					
Age .3 d	.92	.85	.84	.89	.83
Age: 28 d[b]	.92	.75	.73	.89	.78

[a]No significant differences among positions by chi-square analysis ($\alpha = .05$). Values presented are proportions.

[b]Weaning.

TABLE 3. LEAST SQUARES MEANS FOR SUBSEQUENT ANOGENITAL DISTANCE AND PREDICTED TESTES WEIGHT IN PIGS FROM DIFFERENT INTRAUTERINE POSITIONS DURING PRENATAL DEVELOPMENT[a]

	Intrauterine position					
Item	0E	0M	1M	2M	1E	SD[b]
Anogenital distance[c]						
Birth, mm						
Males	122.4	118.4	121.8	122.8	125.4	9.3
Females	9.9	9.2	9.5	9.8	9.5	1.3
120 d, mm						
Males	492.8	491.4	472.7	455.5	470.0	32.1
Females	34.1	32.8	33.6	30.6	29.8	4.8
Predicated testes						
Wt, g[c]	421.0	402.0	422.0	387.0	406.0	79.5

[a]Means adjusted for farrowing group and litter effects.

[b]Standard deviation.

[c]No significant differences among positions ($\alpha = .05$).

of sperm observed were morphologically abnormal.

Discussion

In general, intrauterine position appeared to have little influence on survivability and phenotype in swine. In terms of birth weight, absolute uterine position was more important than relative intrauterine position. For example, piglets that developed in utero at the tips of the horns tended to be larger at birth than their more caudally located littermates, perhaps due to variation in space available for growth or to differential availability of nutrients. Previous reports have indicated that birth weights of mice also were independent of relative intrauterine position (vom Saal and Bronson, 1978; vom Saal, 1981).

Intrauterine position had no effect on postnatal growth rate of swine of either sex when pigs had ad libitum access to feed. Similar findings have been presented both for rats (Tobet et al., 1982; Richmond and Sachs, 1984) and for mice (Kinsley et al., 1986b), although another report indicates an advantage in BW for mice of both sexes that had developed between males in utero (Kinsley et al., 1986c). Tobet et al., (1982) indicated that whereas intrauterine position does not affect BW in rats, the sex ratio (proportion of males) in utero is correlated with weight at birth and

TABLE 4. LEAST SQUARES MEANS FOR SUBSEQUENT SEMEN CHARACTERISTICS FOR BOARS FROM DIFFERENT INTRAUTERINE POSITIONS DURING PRENATAL DEVELOPMENT[a]

	Intrauterine position						
Item	0E	0M	1M	2M	1E	SD[b]	Signif.
No.	7	11	19	21	5		
Total volume, ml	207.5	156.9	225.6	208.0	215.9	63.2	.12
Strained volume, ml	150.9	113.3	165.6	162.2	165.6	49.5	.10
Concentration, sperm/ml $\times 10^6$	16.9	17.5	16.5	18.0	16.6	10.6	NS[d]
Sperm/ejaculate, $\times 10^9$	1,847.9	1,874.9	2,154.7	2,844.1	2,260.1	798.8	NS
Motility, %[c]	81.9	88.9	71.8	71.9	76.8	12.5	NS
Abnormalities, %[c]	8.4	8.9	8.4	11.8	3.2	4.2	.05

[a]Means adjusted for farrowing group, litter, testicular dimensions and body weight.

[b]Standard deviation.

[c]Analysis performed on transformed values (log (x+1)).

[d]NS = not significant.

55 d of age. However, regression analysis of data in the present study indicated that sex ratio had no effect on pig weights.

Although growth rate of pigs was not influenced by intrauterine position when feed was continuously available, this was not true when feed was limited. Under such conditions, 2M males gained more weight than did males from the other groups. This might be explained in two ways, either by a direct effect of prenatal environment on growth potential or as an indirect effect of prenatal environment through its effect on behavior. In rodents, 2M males and females were more aggressive than 0M individuals of the same sex (vom Saal and Bronson, 1978; vom Saal et al., 1983). Such also might be the case in male swine. Because pigs were fed in a single meal from the floor, 2M males may have had a competitive advantage due to their more aggressive tendencies. Results of paired food competitions between penmates indicated that 2M males dominated 60% of competitive encounters and were most successful when competing with males that had developed in utero adjacent to females only (62% vs 0M males and 73% vs 0E males; K. A. Rohde Parfet, unpublished data). The lack of any similar trends in weight gain of females during limit feeding may be related to the larger size of the female group (six vs three animals/pen), resulting in more complex dominance relationships. Alternatively, the larger pens used to house females may have made defense of the feeding area more difficult.

Intrauterine position had no apparent effect on semen characteristics of boars. However, this conclusion is based on results of a single semen collection. Although collection of more samples might have increased the possibility of detecting differences due to intrauterine position, this practice was precluded by time constraints.

Implications

Overall, the results of this study suggest that intrauterine position has little effect on phenotypic characteristics (BW, anogenital distance) and survivability of swine. Moreover, the lack of differences in either predicted testes weight or semen characteristics suggests that, from a physical perspective, reproductive potential of boars was not affected by previous intrauterine position. However, the advantage in weight gain expressed by 2M boars under a limited, and therefore competitive, feeding schedule indicates that intrauterine position may affect some behavior patterns in swine.

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