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The effect of gilt age at first estrus and breeding on third estrus on sow body weight changes and long-term reproductive performance[1]

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ABSTRACT: The objective of this trial was to determine the effect of age at first estrus on BW changes and long-term reproductive performance of sows. At approximately 100 d of age, prepubertal C22 gilts (n = 431) were allocated to trial. At a pen average of 140 d of age, gilts began daily direct contact with mature boars to stimulate onset of puberty. Gilts (n = 317, 73%) were recorded as cyclic by 180 d of age (select) and were classified on the basis of age at puberty into 3 puberty groups: 1) early puberty (EP; <153 d of age; n = 85); 2) intermediate puberty (IP; 154 to 167 d of age; n = 140); or 3) late puberty (LP; 168 to 180 d of age; n = 90). Gilts not exhibiting the standing reflex by 180 d of age were considered nonselect (NS; n = 91). Mean day to puberty and age at puberty attainment in each of the classifications were EP: 9.6 ± 0.5 d and 147.4 ± 0.5 d; IP: 19.3 ± 0.5 d and 159.9 ± 0.3 d; LP: 33.8 ± 0.7 and 175.7 ± 0.6 d, respectively. Fewer NS gilts (73.0%) were bred than were EP (97.7%), IP (93.2%), or LP (93.0%) gilts ($P < 0.05$). Total number of piglets born and born alive were not different between classifications and increased ($P < 0.05$) over successive parities in EP, IP, and NS gilts. For gilts initially served, there was no effect of puberty group classification on retention in the herd to farrow a third litter, but the rate of fallout per parity tended to be greatest for NS (17.2%) compared with EP (12.4%), IP (15.6%), and LP (14.2%) gilts ($P < 0.08$). Taken together, these data suggest that the response to a standardized protocol of boar stimulation can identify 50 to 75% of gilts that will have greatest lifetime productivity in the breeding herd. In the known cyclic (select) gilts, BW increased over the productive life of the sow, and EP gilts were lighter than LP gilts at every measured event ($P < 0.05$). Plasma IGF-1 only differed between puberty groups at d 100 of age (EP: 169.0 ± 4.4; IP: 157.2 ± 3.5; LP: 144.0 ± 4.4 ng/mL), suggesting a mechanism linking IGF-1 status and age at puberty in the present study.

Key words: fertility, lifetime production, puberty

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INTRODUCTION

One of the most critical factors driving the reproductive performance of the sow herd is gilt development and management. Large variation exists with respect to the successful introduction of high-value replacement gilts and retention in the breeding herd (Culbertson, 2008). Approximately 50% of sows are culled every year and wean only 30 to 40 piglets per lifetime. Greater replacement rates due to poor longevity increase the number of replacement gilts needed (Serenius and Stalder, 2004), and as reviewed by Engblom et al. (2007), at least 3 litters are required from a sow before there is a financial benefit for the producer. Developing management practices that identify gilts with the greatest potential for lifetime performance is crucial to the productivity of conventional production systems. Even minor improvements in gilt management can lead to large increases in breeding herd efficiency by meeting replacement targets from smaller pools of select gilts with improved lifetime performance (Foxcroft et al., 2006).

Rozeboom et al. (1996) did not observe a relationship with age at first conception and longevity, in contrast to Koketsu et al. (1999) who identified age at first estrus as a determinant of lifetime performance. In relation to body state, Rozeboom et al. (1995) suggested that rather than achieving a certain level of body composition, BW, growth rate, or backfat, the attainment of puberty may be related to a metabolic state at a critical period of development. In addition, in other do-

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mestic species, leptin and IGF-1 have been recognized as playing a role in the regulation of growth and body composition and the onset of puberty (Cosgrove et al., 1997).

The primary objective of this study was to confirm the effect of age at first estrus on long-term reproductive performance in contemporary genotypes and production settings in gilts. Associated changes in sow BW, body composition, and IGF-1 and leptin status, were also measured.

MATERIALS AND METHODS

This study was conducted at the Prairie Swine Center, Floral and Elstow production facilities and was approved by the University Committee on Animal Care and Supply, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.

Animals

Between August 2001 and February 2004, 431 prepubertal C22 (L42 dams × L19 sire) gilts (PIC, Winnipeg, Manitoba, Canada) born to multiparous sows were used in this study. Gilts were on study from approximately 100 d of age to breeding after third parity. Gilts were culled as necessary for failure to exhibit a pubertal estrus, failure to conceive, abortion, low productivity, locomotion problems, emaciation, and death.

Gilt Development

In the gilt development unit, gilts were housed in pen groups of 20 on partially slatted floors, provided artificial light from 0700 until 2100 h and permitted at least 0.7 m^2 of space allowance throughout the gilt development and puberty stimulation phases. All gilts were allowed ad libitum access to water and to diets from one 4-holed feeder in each pen. Temperature was monitored and recorded daily using a minimum/maximum thermometer. Gilts were allocated to trial at a pen average of 100 d of age.

Puberty Stimulation

For the purpose of this study, and within the existing gilt development unit, a boar exposure area was designed. Each day, starting at approximately 140 d of age, pens of gilts were taken to the boar exposure area and received 20 min of direct exposure to a boar as a pen group. At all times during the study, 4 mature epididiectomized boars were continuously housed and used in the boar exposure area, and a gilt:boar ratio of no greater than 10:1 was maintained during stimulation. New boars replaced older boars on a regular basis to ensure the boars did not get too large and to maintain boar libido. Boars were not permitted to breed a gilt; however, to maintain libido, boars were routinely permitted to mount a gilt expressing the standing heat reflex and were hand collected by a technician. Physical signs of pending estrus in gilts, such as redness, degree of swelling, and mucosal discharge from the vulva, were recorded once daily during the stimulation period. Puberty attainment was determined as the day gilts first exhibited the standing reflex in response to contact with a boar.

Gilts recorded as cyclic by 180 d of age and collectively considered to be select gilts were classified on the basis of age at puberty into 3 groups: 1) early puberty (**EP**; <153 d of age; n = 85); 2) intermediate puberty (**IP**; 154 to 167 d of age; n = 140); or 3) late puberty (**LP**; 168 to <180 d of age; n = 90). Gilts not exhibiting the standing reflex by a pen average of 180 d of age were considered nonselect (**NS**; n = 91). These NS gilts were, nevertheless, relocated to the breeding barns where staff employed various methods, including the use of a combination dose of 400 IU of eCG and 200 IU of hCG (PG600, Intervet USA, De Soto, KS) and further puberty stimulation to induce puberty in NS gilts. Lifetime performance of all gilts was monitored at several time points and referred to as the following events: d-100, puberty, breeding, farrowing and weaning for parities 1, 2, and 3. On the basis that only known cyclic (select) gilts would be chosen for production, measures of metabolic state over 3 parities in these gilts were only recorded on EP, IP, and LP gilts.

Breeding and Management

On the day that gilts exhibited pubertal estrus they were removed from their original pen, relocated to a pen designated for cycling gilts, and continued to have ad libitum access to the gilt finisher diet and water. From d 18 of their first estrous cycle, gilts were permitted daily fenceline contact with a rotation of 4 mature boars for detection of second estrus. After detection of second estrus, gilts were randomly and evenly relocated to the Floral (300-sow unit) or Elstow (600-sow unit) breeding barns within 7 d of the onset of second estrus. At Floral and Elstow, gilts were initially housed in pen groups of 3 to 6. At approximately d 18 of the second estrous cycle, gilts were permitted fenceline contact with mature boars for detection of third estrus. At all times during their second estrous cycle, gilts had ad libitum access to feed. At first detection of the standing reflex and every 24 h for the duration of third standing heat, select gilts were inseminated using pooled semen at a dose of 3.0×10^9 morphologically normal sperm (PIC) per insemination. Semen used was no older than 3 d from the collection date. The NS gilts were not specifically bred at third estrus and did not necessarily accumulate the extra nonproductive days (**NPD**) involved in delaying breeding to third estrus in EP, IP, or LP gilts. All gilts and sows were allowed fenceline contact with mature boars during insemination.

After breeding, gilts at both facilities were housed in small group pens of 4 to 6 sows (Floral) or large group housing of 20 to 30 sows (Elstow) until farrowing. In all

Table 1. Calculated nutrient composition of diets fed to gilts

Nutrient (as-fed basis)	Gilt finisher	Gestation	Lactation
DE, Mcal/kg	3.30	3.15	3.45
CP, %	23.8	15.4	21.0
Lys, total, %	1.31	0.60	1.10
Ca, %	0.70	0.85	0.81
P, total, %	0.60	0.75	0.65
Cu, mg/kg	50	50	50
Fe, mg/kg	80	80	80
Mn, mg/kg	25	25	25
Se, mg/kg	0.1	0.1	0.1
I, mg/kg	0.5	0.5	0.5
Zn, mg/kg	100	100	100
Biotin, mg/kg	0.2	0.2	0.2
Folacin, mg/kg	2	2	2
Niacin, mg/kg	35	35	35
Pantothenic acid, mg/kg	15	15	15
Riboflavin, mg/kg	5	5	5
Thiamin, mg/kg	1	1	1
Vitamin B_{12}, mg/kg	0.025	0.025	0.025
Vitamin K, mg/kg	4	4	4
Vitamin A, IU/kg	8,250	8,250	8,250
Vitamin D, IU/kg	825	825	825
Vitamin E, IU/kg	40	40	40

other respects, all gilts were managed similarly and fed according to body condition throughout gestation using established production protocols.

Farrowing and Weaning Management

At approximately d 110 of gestation, sows were relocated to the farrowing room and offered the standard lactation diet (Table 1) at approximately 3.0 kg/d, split into 3 meals of approximately the same size at 0800, 1130, and 1530 h. Sows were fed at the discretion of the farrowing room personnel on the day of parturition. Piglets were processed (ear notching, cutting teeth and tails, and iron injection) within 24 h after birth. To standardize litters to 9 to 11 piglets, cross-fostering across treatment was performed within 48 h after birth. At farrowing, total piglets born (**TB**), total born alive (**TBA**), stillborn, and mummified were recorded. Lifetime TB and lifetime TBA over 3 parities was calculated by summing the number of pigs produced in each parity (1 to 3), in those parities that a litter was produced. Lifetime total pigs adjusted and lifetime total pigs born alive adjusted was calculated by summing the number of pigs produced for all gilts that were initially served. In any parity that a sow did not produce a litter, TB and TBA were recorded as 0. Sow BW, loin depth (**LD**), and backfat depth (**BFD**) were determined within 7 d after parturition. A 21-d lactation room turnover was maintained; subsequently, lactation length varied among sows. At weaning, all pigs were removed, and sows were relocated to gestation stalls (Floral) or large group housing (Elstow). Sow BW, LD, and BFD were again determined within 7 d after weaning. Once per day, beginning 3 d after weaning, sows were permitted fenceline contact with a mature boar for detection of estrus. Weaning-to-estrus interval (**WEI**) was recorded. At the detection of standing heat and every 24 h for the duration of standing heat, sows were inseminated using pooled semen at a dose of 3.0×10^9 morphologically normal sperm (PIC) per insemination. At approximately d 18 after the first detection of estrus, sows were permitted fenceline contact with a mature boar for detection of return to estrus in both facilities. Any sow detected in heat was inseminated again using pooled semen at a dose of 3.0×10^9 morphologically normal sperm (PIC) per insemination. Real-time ultrasound at approximately d 30 of gestation was used to determine a positive pregnancy at the Floral facility only. The same management procedures were followed for parity 2 and 3 weaned sows.

Retention, Culling, and Removal

The day of entry into the breeding herd inventory was set at 170 d of age. At this age, the average gilt weighed approximately 120 kg and was still marketable as a finisher pig. Overall retention rate was determined by the number of females originally bred and successfully reaching first, second, or third parity. Any sow that returned to estrus within 26 d after first breeding was permitted to be rebred. After a second failure to conceive, the sow was considered culled and removed from the study.

Reasons for removal and culling were classified into 4 categories: 1) reproductive failure (conception failure, failure to farrow, no observed heat, abortion); 2) poor productivity (farrowing productivity, lactation-weaning productivity, difficult farrowing, smaller litter size, retained pigs); 3) physical fitness (lameness, unsoundness, injury, downer syndrome, body condition); or 4) disease and health-related problems (rectal and uterine prolapse, vulval discharge, hernia, gastrointestinal complications, urinary infection, abscess, mastitis, heart failure, behavior, unknown; Lucia et al., 2000).

Gilt and Sow Feeding

Gilts and sows were fed commercial diets that were least-cost formulated. Diets for both farms were made at the facility-owned feed mill using the exact same ingredients and batches The ingredient composition of the diets, therefore, varied, but the nutrient composition of the diet remained constant (Table 1).

BW and Metabolic Changes in EP, IP, and LP (Select) Gilts

Ultrasound and BW Measurements. Gilts and sows were weighed, and BFD and LD were determined ultrasonically (Ultra Scan 900, Classic Medical Inc., Tequesta, FL) by experienced technicians at ≈100 d of age, puberty or d-180 cutoff, first breeding, and farrowing and weaning for 3 consecutive parities. A single longitudinal scan using a 3.5-MHz linear probe was obtained by placing the transducer probe parallel to the midline of the gilt and approximately 7 cm from the midline. The scan was measured from the last rib until approximately the third- or fourth-last rib. At the time of ultrasonography, the scan was visually appraised and LD and BFD recorded.

Blood Collection. To determine metabolic hormone status at d 100, puberty, first breeding, and at farrowing and weaning for 3 consecutive parities, two 5-mL jugular blood samples were collected between 0900 and 1400 h into heparinized and nonheparinized tubes from all available gilts and sows during a brief period of nose-snare restraint. All samples were centrifuged at 1,500 × g for 15 min at 4°C and plasma and serum decanted and stored at −20°C until analysis for leptin and IGF-1 concentration.

To ensure that gilts were truly noncyclic, at approximately 170 and 180 d of age, a single 10-mL jugular blood sample was taken during a brief period of nose-snare restraint for analysis of plasma progestagen concentration. Gilts were considered previously cyclic if plasma progesterone concentrations were greater than 4.5 ng/mL, and data from these gilts were removed from the analysis.

RIA

For all RIA, all samples were analyzed in duplicate. The sensitivity of the assay was calculated using the following equation: average of the zero-binding tube [maximal bound (Bmax) − 2SD(Bmax)/average(Bmax)] × 100. Plasma progesterone concentrations were determined using a RIA kit (Coat-a-Count Progesterone, Diagnostic Products Corporation, Los Angeles, CA), previously validated for use with porcine plasma without extraction (Mao et al., 1999). The sensitivity of the assay was 0.1 ng/mL; the intraassay CV was 4.0%; and the interassay CV was 12.1%. Plasma IGF-1 concentrations were determined using the homologous double antibody RIA described by Novak et al. (2002). One hundred microliters of plasma was initially extracted with 3 mL of acid ethanol. Radio inert recovery efficiency was 109%. The intraassay CV was 6.4%, the interassay CV was 8.4%, and the average sensitivity was 23.3 ng/mL. Results for individual assays were corrected to the potency of Bachem recombinant human IGF-I catalog #H3102 vial lot #Z0103. Plasma leptin concentrations were determined using the multi-species double-antibody kit assay previously validated by Mao et al. (1999) for use in our laboratory. For the assays run, the intraassay CV was 7.3%, the interassay CV was 6.2%, and the sensitivity of the assay was 1.2 ng/mL.

Statistical Analysis

All analyses were performed using SAS (SAS Inst. Inc., Cary, NC), with gilt representing the experimental unit for all variables tested. Data were checked for normality and homogeneity of variance, and when these conditions were not met, the data were transformed as necessary. For data that required transformation, the resulting LSM were back-transformed for data presentation, and an error term for the original units was estimated using the untransformed data.

A mixed model (PROC MIXED) for repeated measures was used to analyze BW, LD, BFD, TB, TBA, WEI, leptin, and IGF-1. The model included the fixed effect of puberty group classification (EP, IP, LP, or NS). Barn was considered a random effect, the repeated effect was considered the event (d-100, puberty, breeding, farrowing, and weaning for parities 1, 2, and 3), and the individual sow was the subject on which repeated measures were taken. An appropriate covariance structure was selected by comparing the goodness-of-fit measures from runs that fitted different structures. Lactation length was used as a covariate in the analysis of WEI. A mixed model was used to analyze effects of puberty group classification on entry-to-service interval, percent NPD, total born lifetime (**TBL**), total born alive lifetime (**TBAL**), adjusted total born lifetime (**ATBL**), adjusted total born alive lifetime (**ATBAL**), and parity at removal. The model included the fixed effect of puberty group classification (EP, IP, LP, or NS), and barn was again considered a random effect in these analyses.

Categorical data (proportion of gilts among treatments that were originally served, bred within 7 d after weaning, and reached each event) were analyzed separately using the generalized logit function (PROC CATMOD) of SAS. Linear regressions and tests for heterogeneity of slope were performed in SAS using REG and GLM procedures, respectively. Pearson correlation coefficients (PROC CORR) were determined

Table 2. Summary of the number of gilts/sows reaching successive stages within the original (EP, IP, LP, and NS)[1] categories of the study and from which data were recorded

Item	EP	IP	LP	NS	Overall
No. of gilts available by classification	86	140	91	114	431
Removals due to					
Lameness, tail bite, other[2]	0	0	0	−18	−18
Lost gilt identification[3]	−1	0	−1	0	−2
Progesterone (>4.5 ng/mL)[3]	0	0	0	−5	−5
No. of gilts available for breeding	85	140	90	91	366
Removals due to					
Not bred at 3rd estrus[4]	−14	−14	−12	n/a	−40
Not bred[5]	−1	−9	−7	−23	−40
No. of gilts bred	70	117	71	68	326
No. of gilts farrowed					
Parity 1	61	106	64	57	288
Parity 2	55	81	53	45	234
Parity 3	43	65	41	33	178

[1]Gilts were classified on the basis of age at puberty into 3 select groups: 1) early puberty (EP; <153 d of age); 2) intermediate puberty (IP; 154 to 167 d of age); or 3) late puberty (LP; 168 to <180 d of age). Gilts not exhibiting the standing reflex by a pen average of 180 d of age were considered nonselect (NS; n = 91).

[2]Any gilt removed from trial due to lameness, tail biting, and general health issues before puberty attainment was removed from the analysis.

[3]Retrospectively, sow data were edited and individual sows were removed on the basis of uncertain individual identification and concentrations of progesterone greater than 4.5 ng/mL at d 170 or 180, indicating corpus luteum activity in the absence of a recorded estrus event.

[4]The study protocol stipulated that all gilts were to be first served at third estrus; data from any animal not served at third estrus were also removed from the analysis.

[5]Gilts that were available at the end of the stimulation period but never bred.

for correlations between lifetime growth rate to 100 d of age and gilt age at puberty; and BW, plasma IGF-1 concentrations, and plasma leptin concentrations.

RESULTS

General

Four hundred thirty-one prepubertal gilts were allocated to trial at 101.9 ± 6.6 d of age and 62.1 ± 8.7 (mean ± SD) kg of BW. Any gilt removed from trial due to lameness, tail biting, and general health issues before puberty attainment was removed from the analysis (n = 18). Retrospectively, sow data were edited and individual sows were removed on the basis of uncertain individual identification (n = 2) and concentrations of progesterone greater than 4.5 ng/mL at d 170 or 180, indicating corpus luteum activity in the absence of a recorded estrous event (n = 5). Because the study protocol stipulated that all gilts were to be first served at third estrus, data from any animal not served at third estrus was also removed from the analysis (n = 40). Therefore, 326 animals were initially included in the final analysis, and the number of measurements at each event is indicated in Tables 2 and 3, respectively.

A larger proportion of gilts were initially allocated to Elstow compared with Floral barns (65.5 vs. 35.4%) due to the increased breeding requirements at Elstow. However, the percentage of EP (20.4 vs. 23.0%), IP (38.0 vs. 32.0%), LP (20.4 vs. 24.0%), and NS (21.0 vs. 21.0%) gilts was not different ($P = 0.60$) at Elstow and Floral, respectively.

Puberty Stimulation and Age at Puberty

Gilts began puberty stimulation at 140.0 ± 5.0 d (mean ± SD). Overall, 58.3% (n = 237) and 73.0% (n = 317) of gilts exhibited the standing reflex within 30 and 40 d of puberty stimulation, respectively (Figure 1). Age at puberty varied by 60 d, and data on age at first estrus were normally distributed (Figure 2). Mean day (LSM ± SEM) to puberty and age at puberty attainment in each of the puberty groups were EP: 9.6 ± 0.5 d and 147.4 ± 0.5 d; IP: 19.3 ± 0.5 d and 159.9 ± 0.3 d; and LP: 33.8 ± 0.7 and 175.7 ± 0.6 d, respectively. The NS gilts were identified as nonpubertal at 179.5 ± 0.7 d. Lifetime growth rate to 100 d of age was not related to gilt age at puberty or responsiveness of the gilts to boar stimuli (Figure 3).

BW, LD, and BFD

For BW, there was an effect ($P < 0.05$) of puberty group, event, and a puberty group × event interaction. At d100, EP, IP, and LP gilts were of similar BW ($P > 0.05$; Table 4). At first estrus (standing heat), breeding at third estrus, farrowing and weaning at parity 1, LP sows were heavier than EP or IP sows ($P < 0.05$). At farrowing and weaning at second and third parity, LP sows remained heavier ($P < 0.05$) than EP sows. Within a puberty classification group, BW was different ($P < 0.05$) at each event. There was no difference ($P > 0.05$) in BW loss during lactation among EP, IP, or LP gilts (data not shown). Body weight at breeding of select gilts at third estrus varied by 90 kg, and BW

Table 3. Summary of the number of gilts and sows within the original (EP, IP, LP, and NS)[1] categories for which BW was recorded and blood samples collected (n), and for which data were analyzed at successive stages of the study

Item	EP	IP	LP	NS
100 d of age				
Breed BW	65	100	63	86
Plasma IGF-1 sample	59	89	60	84
Plasma leptin sample	58	94	56	84
Puberty (EP, IP, LP) or d 180 cutoff (NS)				
BW	65	110	64	81
Plasma IGF-1 sample	49	74	45	—
Plasma leptin sample	66	97	64	—
Bred at 3rd estrus				
BW	58	96	57	—
Plasma IGF-1 sample	56	94	56	—
Plasma leptin sample	56	94	56	—
Parity 1				
Farrow BW	55	85	51	—
Plasma IGF-1 sample	47	73	45	—
Plasma leptin sample	49	75	42	—
Wean BW	44	87	46	—
Plasma IGF-1 sample	41	70	42	—
Plasma leptin sample	39	63	38	—
Parity 2				
Farrow BW	47	66	47	—
Plasma IGF-1 sample	37	54	40	—
Plasma leptin sample	44	60	43	—
Wean BW	45	60	42	—
Plasma IGF-1 sample	35	55	35	—
Plasma leptin sample	39	54	37	—
Parity 3				
Farrow BW	37	54	37	—
Plasma IGF-1 sample	37	51	32	—
Plasma leptin sample	37	50	29	—
Wean BW	38	50	36	—
Plasma IGF-1 sample	34	48	32	—
Plasma leptin sample	34	48	32	—

[1]Gilts were classified on the basis of age at puberty into 3 select groups: 1) early puberty (EP; <153 d of age); 2) intermediate puberty (IP; 154 to 167 d of age); or 3) late puberty (LP; 168 to <180 d of age). Gilts not exhibiting the standing reflex by a pen average of 180 d of age were considered nonselect (NS; n = 91).

at breeding was normally distributed (Figure 4); LP and IP gilts represented larger proportions of heavy-BW gilts at breeding (>170 kg).

There was no effect ($P > 0.05$) of puberty group, an effect ($P < 0.05$) of event for LD and BFD (Table 3), and no puberty group × event interaction ($P > 0.05$); only the effect of event on LD and BFD is reported (Table 4). Gilts at 100 d of age had less ($P < 0.05$) LD than at any other measured event. Sows lost ($P < 0.05$) LD during lactation in their first and second parities. Backfat depth was least at 100 d of age and increased until breeding. Sows did not gain backfat during their first gestation, but lost ($P < 0.05$) backfat during their first and third lactations. Backfat at farrowing remained constant over 3 successive parities.

IGF-1 and Leptin Concentrations

Plasma IGF-1 only differed among puberty groups at d 100 (Table 4). Body weight, growth rate, and predicted lean mass at d 100 were not correlated ($P > 0.35$) to plasma IGF-1 at d 100. However, irrespective of puberty group or event, BW was negatively correlated (r = −0.36, $P < 0.001$) with plasma IGF-1, and plasma leptin was positively correlated with BW (r = 0.19, P

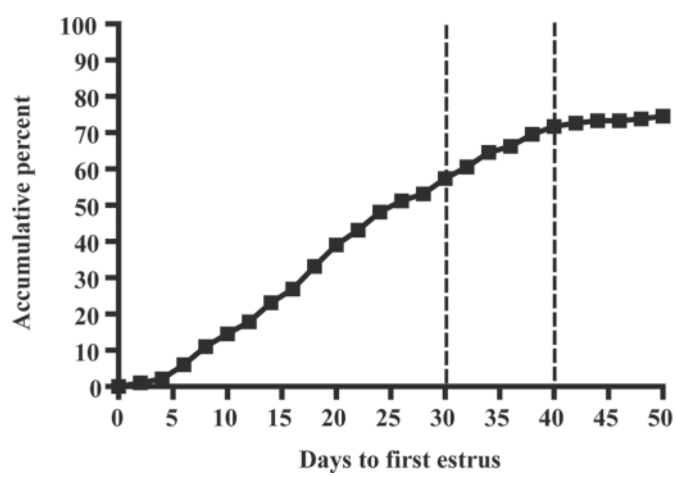

Figure 1. Accumulated percentage of gilts reaching puberty in response to daily contact with a rotation of 4 epididiectomized boars in a puberty stimulation area starting from a pen average of 140 d of age.

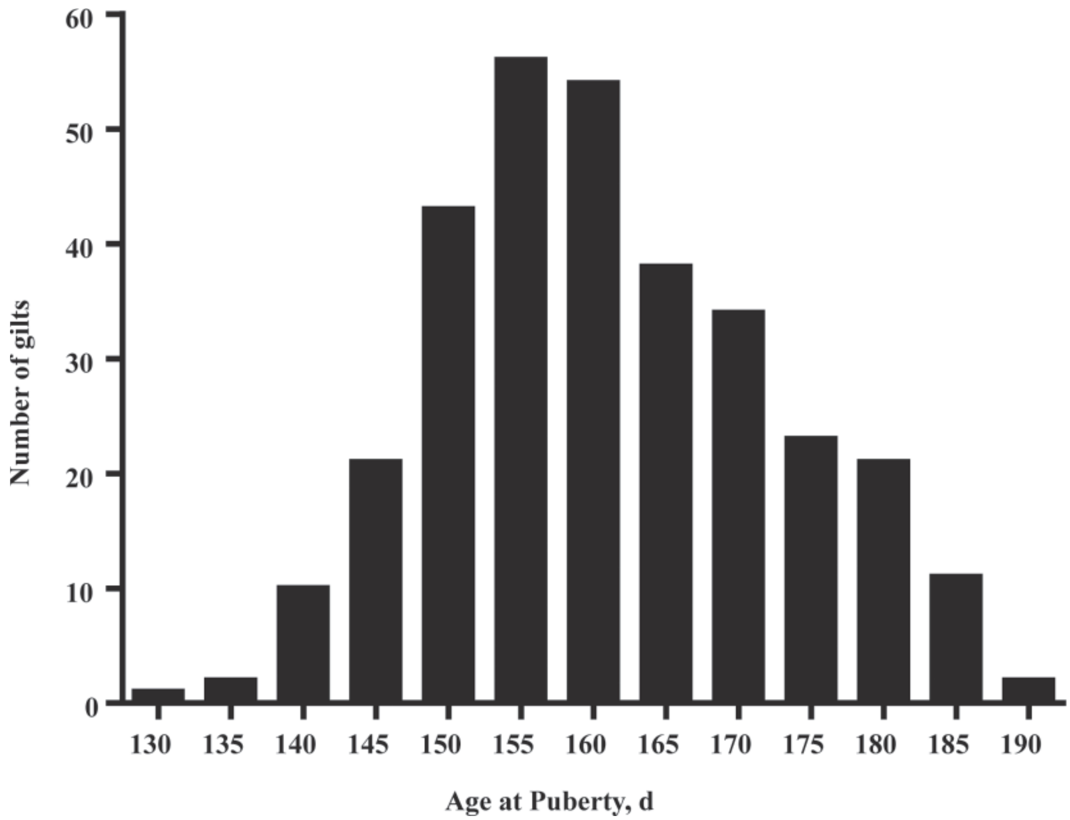

Figure 2. The age of gilts at their first recorded estrus (n = 315) in response to daily direct contact with a rotation of 4 boars for 40 d starting at a gilt pen average of 140 d.

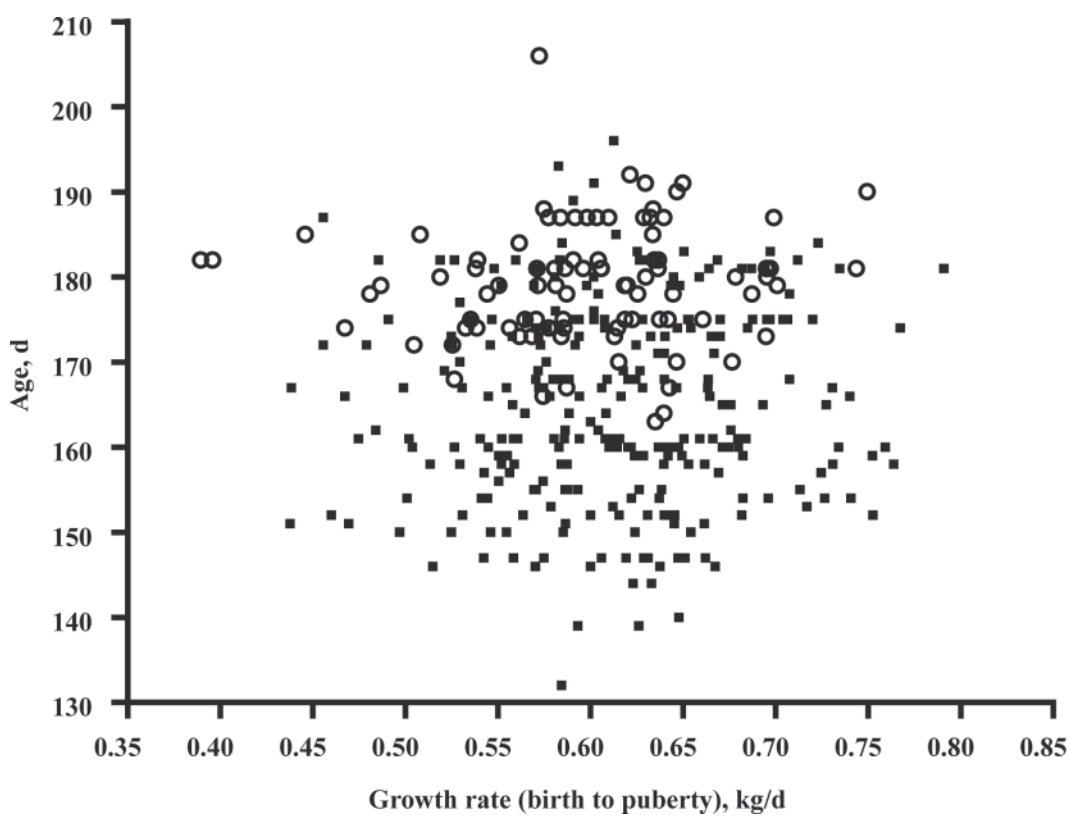

Figure 3. Relationship between growth rate from birth to 100 d of age and age at puberty for select (■, closed squares) gilts or age at removal from the study for nonselect (○, open circles) gilts. Select gilts reached puberty within the 40-d period of boar stimulation. Nonselect gilts did not exhibit standing reflex by a pen average of 180 d of age and, thus, were removed from the study.

Table 4. Body weight, loin depth, backfat depth, IGF-1, and leptin concentrations least squares means (±SEM) for EP, IP, and LP select gilts[1,2]

Item	d 100	Puberty age	Breed	Parity 1 Farrow	Parity 1 Wean	Parity 2 Farrow	Parity 2 Wean	Parity 3 Farrow	Parity 3 Wean
BW, kg									
EP	$60.3 \pm 1.1^{x,a}$	$105.3 \pm 1.4^{x,b}$	$133.6 \pm 1.9^{x,c}$	$182.3 \pm 2.3^{x,d}$	$171.2 \pm 2.3^{x,e}$	$219.5 \pm 2.6^{x,f}$	$211.1 \pm 2.7^{x,g}$	$251.7 \pm 3.3^{x,h}$	$241.7 \pm 3.3^{x,i}$
IP	$61.9 \pm 0.8^{xy,a}$	$118.1 \pm 1.1^{y,b}$	$146.2 \pm 1.5^{y,c}$	$191.7 \pm 1.8^{y,d}$	$179.7 \pm 1.8^{y,e}$	$223.0 \pm 2.2^{xy,f}$	$214.9 \pm 2.2^{xy,g}$	$254.2 \pm 2.8^{xy,h}$	$241.6 \pm 2.7^{x,i}$
LP	$64.0 \pm 1.1^{y,a}$	$128.9 \pm 1.4^{z,b}$	$155.7 \pm 1.9^{z,c}$	$196.4 \pm 2.3^{y,d}$	$186.0 \pm 2.3^{z,e}$	$228.7 \pm 2.6^{y,f}$	$217.6 \pm 2.7^{y,g}$	$262.1 \pm 3.4^{y,h}$	$247.8 \pm 3.4^{y,i}$
Loin depth,[3] mm									
All select	42.2 ± 0.4^{a}	60.4 ± 0.5^{e}	57.7 ± 0.5^{b}	55.9 ± 0.6^{c}	54.2 ± 0.6^{f}	58.3 ± 0.7^{bd}	56.1 ± 0.6^{c}	60.3 ± 0.6^{e}	59.5 ± 0.5^{de}
Backfat depth,[3] mm									
All select	9.0 ± 0.1^{a}	13.2 ± 0.2^{b}	15.0 ± 0.3^{cd}	15.2 ± 0.3^{d}	13.2 ± 0.3^{b}	15.0 ± 0.3^{d}	14.7 ± 0.4^{d}	15.9 ± 0.3^{c}	15.1 ± 0.4^{d}
Plasma IGF-1 concentration, ng/mL									
EP	$169.0 \pm 4.4^{x,a}$	111.3 ± 4.2^{de}	122.0 ± 4.5^{bc}	110.6 ± 4.3^{de}	112.2 ± 4.2^{cd}	104.2 ± 5.2^{de}	$124.3 \pm 4.4^{x,b}$	100.8 ± 5.1^{ce}	111.4 ± 5.4^{de}
IP	$157.2 \pm 3.5^{y,a}$	109.8 ± 3.4^{bd}	119.3 ± 3.5^{c}	109.8 ± 3.4^{bd}	109.3 ± 3.3^{bd}	103.6 ± 4.3^{b}	$108.1 \pm 3.6^{y,bd}$	107.4 ± 4.4^{b}	118.9 ± 4.5^{cd}
LP	$144.0 \pm 4.4^{z,a}$	101.7 ± 4.4^{c}	115.1 ± 4.3^{b}	101.0 ± 4.4^{c}	112.0 ± 4.2^{b}	98.3 ± 5.1^{c}	$112.9 \pm 4.6^{xy,b}$	96.6 ± 5.5^{c}	106.5 ± 5.6^{bc}
Plasma leptin concentration,[3] ng/mL									
All select	2.6 ± 0.05^{a}	2.6 ± 0.06^{a}	3.3 ± 0.09^{b}	2.9 ± 0.08^{cde}	2.8 ± 0.06^{c}	3.0 ± 0.07^{e}	2.9 ± 0.06^{cd}	3.1 ± 0.08^{e}	3.0 ± 0.07^{de}

[a–i]Least squares means within a row and response variable with uncommon superscripts differ ($P > 0.05$).

[x–z]Least squares treatment × event means within a column and response variable with uncommon superscripts differ ($P \leq 0.05$).

[1]Gilts were classified on the basis of age at puberty into 3 select groups: 1) early puberty (EP; <153 d of age); 2) intermediate puberty (IP; 154 to 167 d of age); or 3) late puberty (LP; 168 to <180 d of age). Gilts not exhibiting the standing reflex by a pen average of 180 d of age were considered nonselect and not included in this table.

[2]For n, see Table 2.

[3]For loin depth, backfat depth, and leptin concentration, no group × event interaction existed; therefore, only the effect of event is shown.

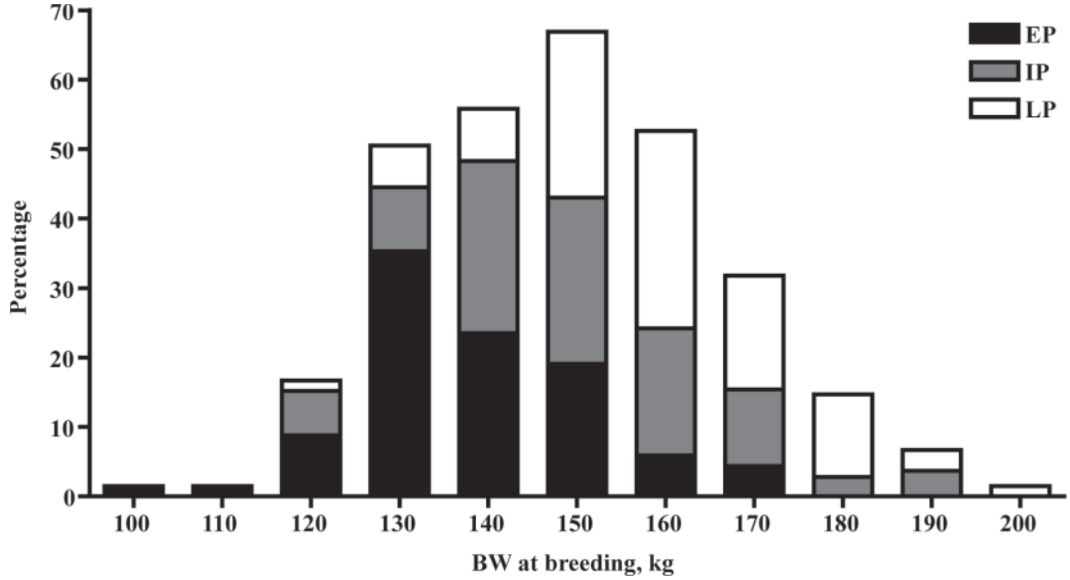

Figure 4. The distribution of BW of select gilts that were recorded as reaching early (EP; <153 d of age), intermediate (IP; 154 to 167 d of age), or late (LP; 168 to <180 d of age) pubertal estrus within 40 d of boar contact and bred at third estrus (n = 281).

< 0.001) and predicted fat mass ($r = 0.19$, $P < 0.001$). Plasma IGF-1 at d 100 was greater than at any other event and, irrespective of puberty, group was negatively correlated with age at standing heat ($r = -0.24$, $P < 0.001$). There was no effect ($P > 0.05$) of puberty group, but a significant effect ($P > 0.05$) of event for plasma leptin concentration (Table 4), and no puberty group × event interaction ($P < 0.05$). Leptin concentration was least ($P < 0.05$) at d 100 and puberty.

Breeding Performance

Age (LSM ± SEM) at first service was different ($P < 0.001$) among puberty groups (EP: 189.7 ± 1.2; IP: 202.5 ± 0.9; LP: 218.3 ± 1.2; NS: 210.8 ± 1.2). A reduced ($P < 0.05$) percentage of gilts originally on inventory and classified as NS were bred (73.0%) than EP (97.7%), IP (93.2%), or LP (93.0%) gilts (Table 5). The entry-to-first-service interval was shortest ($P < 0.05$) for EP gilts and longest for LP gilts, with intervals in IP and NS gilts being intermediate. For EP, IP, LP, and NS puberty classifications, WEI was similar ($P > 0.05$) in the first and third parities. For EP, IP, and LP puberty classifications, WEI was shortened ($P < 0.05$) in parity 3 compared with parity 1. For NS sows, WEI remained constant in all measured parities (Table 5).

TB and TBA Pigs

Total pigs born per litter and TBA were not different ($P > 0.05$) among puberty groups. However, TB and TBA increased ($P < 0.05$) over successive parities in EP, IP, and NS, but not in LP gilts (Table 6). Cumulative TBL and TBAL up to 3 parities for sows that farrowed at least 1 litter was not different ($P > 0.05$) among puberty groups. Similarly, ATBL and ATBAL for sows that were initially served as gilts (and accepting that if gilts did not produce a litter in any subsequent parity, TB and TBA were recorded as 0) were not different ($P > 0.05$) among puberty groups.

Sow Retention Analysis

There was no difference ($P > 0.05$) in parity at removal or reasons for removal among puberty classification groups. Culls attributed to reproductive reasons accounted for the largest proportion of removals for each puberty group classification (Table 7). No overall differences in sow retention to third parity among gilts initially served were detected ($P > 0.12$) among puberty groups (Figure 5). However, for gilts initially served, the slope of the regression line representing retention from first service to farrowing a third litter tended to be less ($P < 0.08$) for NS ($y = -17.2x + 117.7$, $r^2 = 0.99$) compared with EP ($y = -12.4x + 112.9$, $r^2 = 0.98$), IP ($y = -15.5x + 117.6$, $r^2 = 0.98$), and LP ($y = -14.2x + 116.2$, $r^2 = 0.99$) gilts.

DISCUSSION

Successful introduction and retention of high-value replacement gilts into the breeding herd is variable (Culbertson, 2008). Excessive numbers of gilts and sows are culled and replaced every year. Almost 20% of premature culling of females from the breeding herd occurs at parity 0, with 65% of these culls attributed to reproductive disorders or failure (Lucia et al., 2000; Engblom et al., 2008). Developing management practices that produce gilts with a greater potential lifetime performance and decreasing attrition is crucial to the productivity of commercial production systems (Wilson and Ward, 2008).

Table 5. Nonproductive days (NPD) accumulated in the gilt pool and weaning-to-estrus interval (WEI; least squares means ± SEM) and the percentage of gilts and sows bred by 7 d after weaning for select EP, IP, and LP, and nonselect (NS) gilts[1]

Item	EP	IP	LP	NS
Gilt pool NPD				
170 d to 1st service interval	20.4 ± 1.4[a]	32.2 ± 1.1[b]	48.9 ± 1.1[c]	32.2 ± 1.6[b]
Served, %	97.7[a]	93.2[a]	93.0[a]	73.8[b]
WEI,[2] d				
Parity 1	5.0 ± 0.2[x]	4.9 ± 0.2[x]	5.1 ± 0.2[x]	5.0 ± 0.2
Parity 2	4.6 ± 0.24[a,y]	4.8 ± 0.2[b,xy]	4.6 ± 0.2[ab,y]	5.0 ± 0.2[b]
Parity 3	4.7 ± 0.2[y]	4.6 ± 0.2[y]	4.7 ± 0.2[y]	4.8 ± 0.2
Sows bred by 7 d,[3] %				
Parity 1	97.7	85.5	85.4	81.1
Parity 2	91.3	94.4	92.1	95.3
Parity 3	83.3	96.1	90.9	94.6

[a–c]Least squares means within a row with uncommon superscripts differ ($P < 0.05$).

[x,y]Least squares means within a column with uncommon superscripts differ ($P < 0.05$).

[1]Gilts were classified on the basis of age at puberty into 3 select groups: 1) early puberty (EP; <153 d of age); 2) intermediate puberty (IP; 154 to 167 d of age); or 3) late puberty (LP; 168 to <180 d of age). Gilts not exhibiting the standing reflex by a pen average of 180 d of age were considered nonselect (NS).

[2]For those sows bred <10 d after weaning.

[3]No differences were detected among gilt classifications ($P > 0.05$).

Kirkwood and Aherne (1985) predicted that neither gilt age nor BW are reliable indices of reproductive development, and this is supported by the large range of age and BW at which gilts reached puberty in the present study. However, van Wettere et al. (2006) suggested that optimal timing and synchrony of puberty attainment occurs when boar contact commences at 160 d of age. Although delaying the start of puberty stimulation to greater than 190 d results in a more synchronous response to boar stimulation, this limits the ability to discriminate between select and NS gilts (Foxcroft et al., 2006). As part of the experimental design of the present study, boar exposure commenced at approximately 140 d of age and a normal distribution in age at detected first estrus resulted. This permitted an effective examination of the effect of age at puberty attainment on subsequent productivity over 3 parities. Our results confirm those of Kummer (2008) and indicate that with good boar contact, 73% of gilts can be recorded as cyclic within 40 d of daily boar exposure.

Table 6. Total born (TB) and total born alive (TBA) over 3 parities and average over lifetime (least squares means ± SEM) for select EP, IP, and LP, and nonselect (NS) gilts[1,2]

Item	EP	IP	LP	NS
TB				
Parity 1	10.7 ± 0.4[a]	10.7 ± 0.3[a]	11.6 ± 0.4	10.6 ± 0.4[a]
Parity 2	11.1 ± 0.4[a]	11.9 ± 0.4[b]	11.5 ± 0.4	11.3 ± 0.5[a]
Parity 3	12.7 ± 0.5[b]	12.0 ± 0.4[b]	12.6 ± 0.5	12.8 ± 0.6[b]
TBL[3]	29.9 ± 1.4	27.9 ± 1.1	29.3 ± 1.4	27.5 ± 1.6
ATBL[4]	25.2 ± 1.6	24.7 ± 1.3	24.7 ± 1.6	21.8 ± 1.8
TBA				
Parity 1	10.1 ± 0.4[a]	10.0 ± 0.3[a]	10.5 ± 0.4[a]	10.0 ± 0.4[a]
Parity 2	10.5 ± 0.5[a]	10.9 ± 0.3[b]	10.5 ± 0.4[a]	10.6 ± 0.5[a]
Parity 3	11.9 ± 0.5[b]	11.0 ± 0.4[b]	11.8 ± 0.5[b]	12.0 ± 0.6[b]
TBAL[3]	28.2 ± 1.3	26.1 ± 1.0	27.0 ± 1.3	25.8 ± 1.5
ATBAL[4]	23.9 ± 1.5	22.9 ± 1.2	22.8 ± 1.5	20.5 ± 1.7

[a,b]Within a group classification, TB and TBA differed between parity ($P < 0.05$).

[1]Gilts were classified on the basis of age at puberty into 3 select groups: 1) early puberty (EP; <153 d of age); 2) intermediate puberty (IP; 154 to 167 d of age); or 3) late puberty (LP; 168 to <180 d of age). Gilts not exhibiting the standing reflex by a pen average of 180 d of age were considered nonselect (NS; n = 91).

[2]For TB and TBA, the group classification × parity means did not differ ($P > 0.05$). No differences were detected within parity among puberty group classification ($P > 0.05$). For n, see Table 2.

[3]Lifetime cumulative total born (TBL) or born alive (TBAL) up to 3 parities in those parities in which a litter was produced. No effect of group classifications detected ($P > 0.05$).

[4]Lifetime adjusted (ATBL and ATBAL) = lifetime cumulative TB or TBA over 3 parities for all gilts that were initially served. If a sow did not produce a litter in any subsequent parity, TB and TBA were recorded as 0. No effect of group classifications detected ($P > 0.05$).

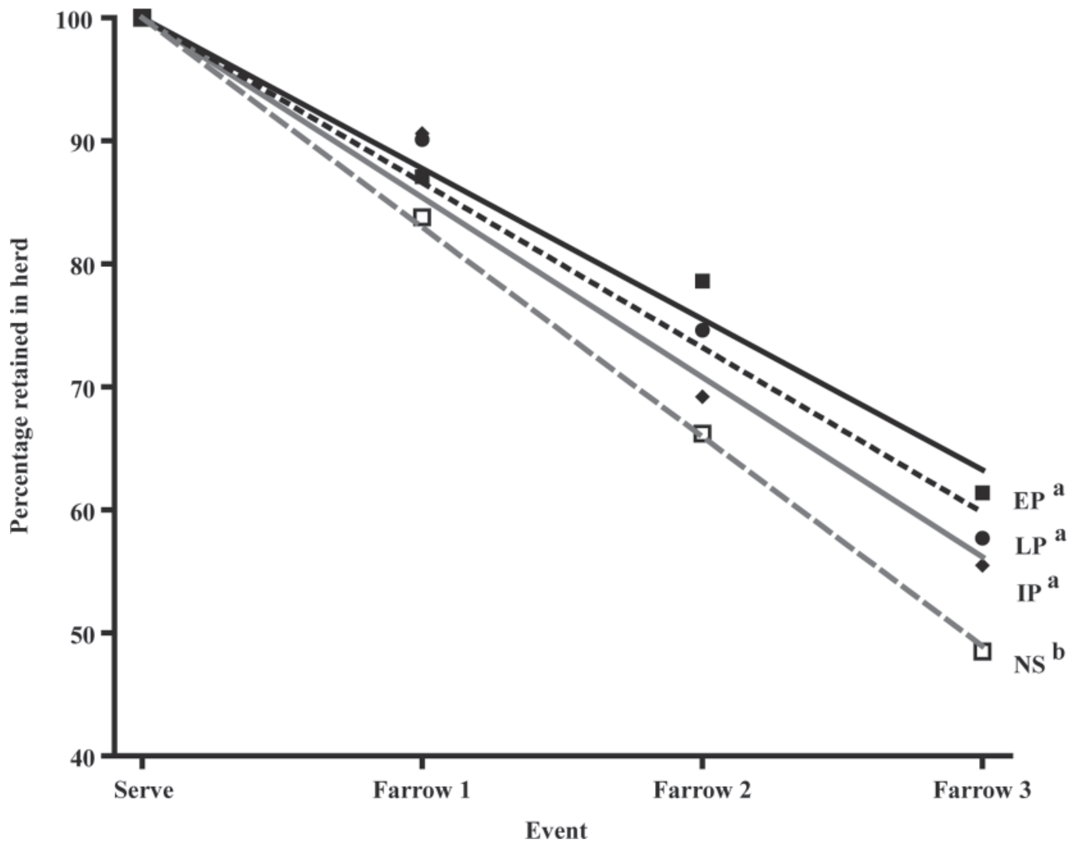

Figure 5. Retention to farrowing at third parity of gilts that were classified as reaching early (EP; <153 d of age), intermediate (IP; 154 to 167 d of age), or late (LP; 168 to <180 d of age) pubertal estrus within 40 d of boar contact and bred at third estrus. Gilts not exhibiting the standing reflex by a pen average of 180 d of age were considered nonselect (NS). Solid black regression line is EP: $y = -12.4x + 112.9$ ($r^2 = 0.98$); solid gray line is IP: $y = -15.5x + 117.6$ ($r^2 = 0.98$); short dashed black regression line is LP: $y = -14.2x + 116.2$ ($r^2 = 0.99$); and gray long dashed regression line is NS: $y = -17.2x + 117.7$ ($r^2 = 0.99$). [a,b]Slopes differ ($P \leq 0.08$) for least squares group classification with uncommon letters.

Kummer et al. (2006) found a significant negative correlation of ($r = -0.36$) between age at puberty and growth rate from birth to 165 d, and their results indicated that slow growth rates delayed puberty. Similarly, Amaral Filha et al. (2009) recently reported that slower growth rates decreased the percentage of gilts showing estrus by 10, 20, and 30 d after the start of puberty stimulation at 130 to 149 d of age. Although it was reported that neither age nor BW may be reliable indictors of onset of puberty, minimum growth thresholds appear necessary. Together with the data from the present study, existing literature supports the earlier conclusions of Beltranena et al. (1993) that, at or above commercially acceptable growth rates (>0.55 kg/d),

Table 7. Parity at removal (least squares means ± SEM) and reason for removal of select EP, IP, and LP, and nonselect (NS) gilts[1]

Item	EP	IP	LP	NS
Parity at removal[2]	1.6 ± 0.2	1.5 ± 0.1	1.5 ± 0.2	1.1 ± 0.2
Reasons for culling, %				
Reproduction[3]	70.0	63.1	63.2	65.8
Litter performance[4]	15.0	18.4	13.2	5.3
Locomotion[5]	7.5	6.2	7.9	13.2
Disease/peripartum problems[6]	7.5	12.3	15.8	15.8

[1]Gilts were classified on the basis of age at puberty into 3 select groups: 1) early puberty (EP; <153 d of age); 2) intermediate puberty (IP; 154 to 167 d of age); or 3) late puberty (LP; 168 to <180 d of age). Gilts not exhibiting the standing reflex by a pen average of 180 d of age were considered nonselect (NS).

[2]No differences were detected among puberty group classifications ($P > 0.05$).

[3]Conception failure, failure to farrow, no observed estrus, abortion.

[4]Farrowing productivity, lactation-weaning productivity, difficult farrowing, smaller litter size, retained pigs.

[5]Lameness, unsoundness, injury, downer syndrome, body condition.

[6]Rectal and uterine prolapse, vulvar discharge, hernia, gastrointestinal, urinary infection, abscess, mastitis, heart failure, behavior, unknown.

there is no relationship between growth rate from birth to the commencement of boar contact and recorded age at puberty.

A consequence of the considerable variability in growth performance in the present study, and the lack of any association of growth rate with age at sexual maturity, was a 60-d difference in age at puberty and a 95-kg BW difference between the lightest and heaviest gilts when bred at third estrus. Gilts classified as IP and LP represented a greater percentage of gilts with >160 kg of BW at breeding. Despite the fact that during the entirety of this experiment, gilts and sows were fed during gestation to achieve a target body condition based on a measured backfat, EP gilts were lighter than LP at every measured event. Therefore, although variation of sow backfat was successfully standardized, BW at first breeding largely dictated ongoing differences in sow BW. From a retention perspective, gilts that are later maturing and mated at heavier BW remain heavier in later parities, with possible detrimental consequences on animal welfare and culling rates. As reviewed by Kummer (2008), gilts bred at >170 kg were at greater risk of having reduced retention to third parity, largely as a result of increased culling due to locomotion problems. However, because puberty stimulation started early (140 d of age) in the present study to ensure that the full range of age at pubertal estrus was determined, most of the LP gilts were still bred <170 kg of BW and the greater BW of late-maturing gilts (155 kg) would not be expected to pose problems for mature body size and, hence, retention rate. Indeed, culls for lameness were minimal and similar between pubertal group classifications, suggesting that the increased body size of LP gilts at first service did not adversely affect retention over 3 parities.

Other than an initial increase in backfat from 100 d of age until breeding, BFD remained relatively constant over 3 parities in the dam-line females used in the present study. These data support the suggestion of Kirkwood (1990) that when gilts are subjected to good management that minimizes BW and condition loss during lactation, there is no association between BW or BFD at first successful breeding and subsequent reproductive performance. From the perspective of using BCS to adjust feed allowances during gestation in many commercial sow herds, the observation in the present study that changes in BW and protein mass were not associated with achieved changes in BFD has important implications. Intuitively, these data suggest that a focus on controlling the BW and protein mass of gilts at breeding would be a more effective management strategy in contemporary dam lines.

Plasma leptin and IGF-1 have been recognized as playing a role in the regulation of both growth and body composition, and the onset of puberty. Decades of selection for improved growth and body composition would be expected to change the interactions among the GH-insulin-IGF-1 endocrine axis (te Pas et al., 2004). Results from the current study confirm previous reports from our group (Patterson et al., 2002) of a positive correlation between BFD and plasma leptin concentrations at 160 d of age. Amstalden et al. (2000) reported in heifers that IGF-1 may increase with the approach of puberty and possibly act at the hypothalamic-pituitary gland level to modulate gonadotropin secretion. Conversely, Lamberson et al. (1995) reported no relationship between plasma IGF-1 concentration and age at puberty in growing pigs. In the current study, greater plasma IGF-1 concentration at d 100 was associated with gilts reaching puberty at an earlier age. However, this difference in plasma IGF-1 was no longer apparent at the time of puberty, supporting similar results in the study of Yelich et al. (1996) in heifers, fed to achieve faster and slower growth rates. Sensitization of the ovary by enhanced IGF-1 to the presumed increase in tonic LH that is triggered by boar stimuli (Kingsbury and Rawlings, 1993) would be an effective mechanism linking IGF-1 status and age at puberty in the present study. A similar IGF-1 associated mechanism has been implicated as the link between sow metabolic state at weaning and ovarian response to the increase in gonadotrophins triggered by weaning (Cosgrove et al., 1997).

For analysis of NPD, entry into the breeding herd was set at 170 d of age, at which time gilts were approximately 120 kg of BW because below this age and BW culled gilts shipped could still be sold at market-hog prices. As would be expected, NPD accumulated from 170 d of age to first service was least for EP gilts and greatest for LP gilts. Fewer NPD were accumulated for NS gilts than LP gilts because they were not specifically bred at third estrus and did not necessarily accumulate the extra NPD involved in delaying breeding to third estrus in EP, IP, or LP gilts. Nevertheless, the percentage of gilts served was greater for select (EP: 97.7; IP: 93.2; LP: 93.0%) than for NS (73.8%) gilts. In contrast to Sterning et al. (1998), we did not detect a relationship between age at puberty and WEI after first weaning, this is not surprising because in most modern sow farms, more than 90% of sows typically return to estrus within 3 to 5 d after weaning (Poleze et al., 2006).

As previously discussed, Kirkwood and Aherne (1985) predicted that neither age nor BW is a reliable index of reproductive development, and this is supported by the large range of age and BW over which gilts reach puberty in the present study. Indeed, Young et al. (2008) recently reported that increased age at first mating (>260 d) may in fact reduce lifetime performance. The results of our study emphasize the value of knowing physiological age at breeding (recorded pubertal estrus and number of estrous cycles) rather than using chronological age as a possible criterion for determining the time of mating. Kummer et al. (2006) reported for gilts bred at similar ages and BW, those bred at first estrus had decreased TBL, TBAL, and farrowing rate than those bred at their second, third, or fourth estrus. Therefore, because all gilts were initially bred at third estrus in the present study, differences in lifetime reproductive performance can be attributed to factors other than sexual maturity at first mating (estrus at mating).

Williams et al. (2005) recommended that gilts weigh at least 180 kg at first farrowing to minimize protein loss during lactation, and to achieve this, gilts should weigh a minimum of 135 kg at breeding. Furthermore, Williams et al. (2005) reported that gilts weighing less than 135 kg had fewer TBL over 3 parities than gilts weighing over 135 kg. However, there was no further increase in TBL for gilts bred between 135 and 170 kg, indicating there is no productive advantage to breed gilts at heavier BW. In fact, in 2 different studies (Williams et al., 2005; Amaral Filha et al., 2009) a greater percentage of gilts bred at greater than 170 kg were culled due to lameness before reaching 3 parities. Within parity in the present study there were no differences between puberty classifications in TB and TBA, but as would be expected, litter size increased with increasing parity. It may not be surprising then that no difference in litter size was seen among puberty classifications because all gilts were bred at third estrus by design and the majority of gilts (67%) were bred at or above the 135 kg of BW target at breeding. Although ATBL was not significantly different among puberty classifications, select gilts gained 3.0 and 2.7 TBL and TBAL, respectively, compared with NS gilts, representing a potential economic gain to the producer. Supporting these results, Young et al. (2008) recently reported that gilts that attain puberty at a younger age (<185 d) had greater TBL (+2.5), TBAL (+2.3), and total pigs weaned (+1.9) over their first 3 parities than gilts attaining puberty at an older age (>185 d).

Despite ensuring standardized and relatively advanced sexual maturity at breeding in the present study, removals from the herd up to parity 3 were still largely attributable to reproductive failure, and these results are consistent with other studies (Stein et al., 1990; Lucia et al., 2000; Engblom et al., 2008). Furthermore, Engblom et al. (2008) suggested that unplanned involuntary culling for reproductive failure and locomotion were most common in low parities, and as parity increased, designated culling for low production and old age increased. Lucia et al. (2000) suggested that minimizing removals for reproductive failure was critical for optimizing lifetime reproductive efficiency. Furthermore, reproductive management practices should be directed at reducing NPD accumulation during the early reproductive cycles, which could be achieved by implementing improved gilt management practices. At least 3 parities were required before there was a financial benefit for the producer (as reviewed by Engblom et al., 2007). Lucia et al. (2000) suggested that a reduction in the proportional accumulation of NPD can be achieved by breeding females earlier after they were placed on inventory. This can be achieved by early exposure to boars (140 to 160 d of age) to stimulate early onset of puberty, after which gilts can be managed to maximize their fertility at breeding.

In conclusion, gilts known to have reached puberty within 40 d of good boar contact provided an advantage in terms of the increase in percentage of animals served, retention rate and reduced physical body size at mating compared with those that were nonpubertal. These data suggest that the response to a standardized protocol of boar stimulation can be used to identify gilts that are likely to be most fertile over their productive lifetime in the breeding herd. Although the strategy of mating all gilt puberty groups at third estrus results in no major responses in terms of ATBL over 3 parities, there was considerable variation in BW at breeding. Further improvements in the efficiency of breeding herd management would include strategies that use boar stimulation programs to establish known cyclic select gilts and control BW at first mating by allowing gilts to be bred at first, second (preferred), or third estrus.

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