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Incidence and Inheritance of Splayleg in Nebraska Litter Size Selection Lines

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Incidence and Inheritance of Splayleg in Nebraska Litter Size Selection Lines

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Summary and Implications

Incidence of abnormalities at birth is low in most populations, but accounts for a significant proportion of preweaning deaths. Splayleg pigs (SL) is the most common defect in newborn pigs and a high percentage of SL pigs die before weaning. In research at other institutions, SL incidence was associated with the Landrace breed and with large litters; however, a genetic association with litter size was not demonstrated. The University of Nebraska selection lines originated from a Landrace-Large White composite population and have been selected for 22 generations for increased litter size. These lines provided an excellent resource for the objectives of this study, which were 1) to identify traits associated with the SL condition, 2) to estimate genetic parameters for SL, and 3) to estimate the correlated response in incidence of SL to selection for increased litter size. Variables associated with the SL condition were sex, line, generation, line by generation interaction, birth weight, dam's number of live pigs born, dam's number of nipples, dam's age at puberty, dam's embryonic survival, and inbreeding of the dam. Boars were 234% more likely to display SL than gilts ($P < 0.01$). Decreased birth weight was associated with an increase in likelihood of SL ($P < 0.01$). The percentage of SL pigs increased as litter size increased ($P < 0.01$). Increased incidence of SL occurred in litters by gilts that reached puberty at younger ages ($P < 0.01$) and that had fewer nipples ($P < 0.05$). Decreased embryonic survival to d 50 of gestation also significantly increased the probability of SL pigs in the litter ($P < 0.05$). Inbreeding of the pig did not significantly affect the incidence of SL, but the likelihood of SL increased with dam's inbreeding ($P < 0.05$). Estimates of 0.16 for maternal heritability and 0.32 for genetic correlation between number of pigs born alive and SL were obtained. Selection to increase litter size was not associated with genetic potential of individual pigs to be born with SL. However, selection for increased litter size indirectly increased the genetic potential for sows to create a uterine environment more likely to produce litters with SL pigs. The SL condition should be treated as a trait of the sow, rather than the individual piglet.

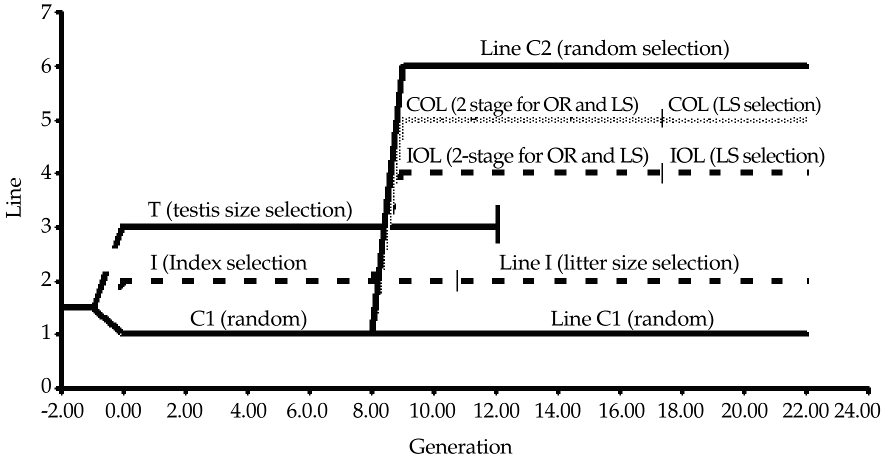

Figure 1. Evolution of the NE selection lines: C1 & C2 = random selection lines, I = Index selection line, COL & IOL = 2-stage selection lines for ovulation rate (OR) and litter size (LS).

Introduction

Splayleg (SL), also commonly called spraddle leg, is the most common birth defect in pigs and survival of pigs with SL is approximately 50%. The incidence of SL pigs has been reported to be greater in Landrace than in other breeds and increased incidence of SL has been associated with larger litters.

Four selection lines, three selected for litter size and its component traits and one selected for testis size, were created from a Large White–Landrace composite population with the objective to improve litter size. Selection for litter size and its components effectively increased litter size in three lines. Testis size increased approximately 50% in 10 generations of selection, but correlated response in litter size was not significant.

Incidence of SL and data on other traits were collected on pigs in these selection lines and their randomly selected controls and analyzed with the objectives of 1) to identify variables affecting the incidence of SL, 2) to estimate genetic parameters for SL, and 3) to estimate correlated responses in incidence of SL to litter size and testis size selection.

Methods

Population

Development of the Nebraska selection lines is illustrated in Figure 1. A base, composite population of Large White and Landrace was formed in 1979. After two generations of random mating, a line selected for increased index of ovulation rate and embryonic survival (Line I), a control line (C1), and a testis size selection line (Line T) were created and selection began. Line I was selected for an index of ovulation rate and embryonic survival to increase litter size. Line C1 was randomly selected. Line T was selected for increased weight of testes; weight was predicted from testes lengths and widths measured at 150 d of age. Twelve generations of selection were practiced in Line T and the line was terminated.

Index selection in Line I was terminated after 11 generations and selection for increased number of fully formed pigs per litter was practiced from Generations 12 through 14. During Generations 15 to 19, between litter selection for number of live pigs born and within litter selection for increased birth weight was practiced in Line I and selection during Generations 20 to 22 was for increased number of live pigs born and within litter selection for increased growth rate, decreased backfat and increased *longissimus* muscle area. Lines I, T and C1 were contemporary in a group that farrowed each year during July and August.

Selected, Generation 8 parents in Lines C1 and I were re-mated within line after females produced their first litter to create a control line and two lines in which two-stage selection for ovulation rate and number of fully formed pigs was practiced. Pigs in Line C1 second parity litters were randomly assigned within litter to a control line (designated Line C2) or to a two-stage selection line (Line COL). The Line I litters were the base for the other two-stage selection line (Line IOL). Lines IOL, COL, and C2 were contemporary and farrowed at a six-month interval to lines I and C1. Generations in Lines IOL, COL, and C2 will be referenced from the initiation of selection in the base composite population. Selection in Lines IOL and COL during Generation 17 for litter size and birth weight, and subsequent selection for litter size, growth, backfat and *longissimus* muscle area was as described above for Line I.

Data

Within 24 hours of birth, sex, birth weight (BWT), number of nipples (NN) and birth abnormalities were recorded. Age at puberty (AP) was recorded in gilts of Lines I and C1 from Generation 2 through Generation 15, in Line T through Generation 12 and in gilts of Lines IOL, COL and C2 through Generation 16. Ovulation rate (OR) was recorded in gilts of Lines I and C1 through Generation 11, and in gilts of Lines IOL, COL and C2 through Generation 16. Embryonic survival (ES), the

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proportion of embryos at day 50 to ovulation rate, was recorded in gilts of Lines I, and C1 from Generations 1 to 11. Age at farrowing (AF) was recorded in all females with litters and number of fully formed pigs (FF), number of mummified pigs (MUM), number of stillborn pigs (SB), and number of pigs born alive (BA) were recorded in all litters. The inbreeding coefficient of each pig was calculated.

A total of 37,673 records on pigs born alive were used. Table 1 shows the number of pigs born alive, number of SL pigs, number of gilts with AP, OR, and ES records by line and generation since initiation of selection in 1981. Splayleg pigs were not recorded in Generation 0 or in Generation 9 in Lines IOL, COL, and C2.

Statistical procedures

Birth weight and the SL condition were considered to be traits of the pig, but modeled with a maternal component. All other traits were considered as traits of the dam (i.e. dam's age at puberty, DAP, dam's age at farrowing, DAF, etc.). Incidence of SL, coded as 0 or 1 in individual pigs, was analyzed with a generalized linear model to determine variables associated with it. If associations between SL and other traits were significant ($P < 0.10$), variances, direct and maternal heritabilities, genetic correlations and breeding values were estimated with linear animal models.

Table 1. Number of observations for pigs born alive (BA), splayleg pigs (SL), age at puberty (AP), ovulation rate (OR), and embryonic survival (ES) by contemporary group (CG) and generation.

	CG1[a]					CG2[a]			
Generation[b]	BA	SL	AP	OR	ES	BA	SL	AP	OR
1	1409	50	—	150	150	—	—	—	—
2	1171	53	255	157	155	—	—	—	—
3	1202	46	278	171	171	—	—	—	—
4	1175	62	282	171	171	—	—	—	—
5	1189	29	326	186	165	—	—	—	—
6	1173	26	288	151	151	—	—	—	—
7	1233	83	290	186	186	—	—	—	—
8	1200	51	286	194	194	—	—	—	—
9 (1)	1152	53	267	177	177	—	—	—	—
10 (2)	1154	84	377	175	175	1164	49	244	193
11 (3)[c]	1299	80	160	210	210	1407	53	—	—
12 (4)	1306	58	145	—	—	1179	41	258	180
13 (5)	921	40	160	—	—	1195	79	232	210
14 (6)	1218	22	159	—	—	1179	47	241	236
15 (7)	1503	49	172	—	—	1224	55	236	225
16 (8)	1350	43	—	—	—	1295	94	247	240
17 (9)	777	20	—	—	—	1085	50	—	—
18 (10)	706	16	—	—	—	1393	83	—	—
19 (11)	696	25	—	—	—	1408	70	—	—
20 (12)[d]	1075	13	—	—	—	298	3	—	—
21 (13)[d]	835	17	—	—	—	351	9	—	—
22	751	10	—	—	—	—	—	—	—
Total	24495	930	3445	1928	1905	13178	633	1622	1407

[a] CG1 = Lines C1, I, and T; CG2 = Lines IOL, COL, and C2.

[b] Generations from initiation of selection in composite founder population. Numbers in parentheses indicate generations of selection practiced in CG2 since diverging from CG1.

[c] Age at puberty and ovulation rate were not measured in Generation 3 gilts in CG2.

[d] Number of observations in CG2 are from Line C2.

Table 2. Percentage increases in likelihood of splayleg for significant effects, expressed as changes from the population mean, in logistic regression models

Trait[a]	Effect/change	Percentage increase[b]
Sex	Male vs female	223.6 **
BWT	-10 g	1.5 **
DBA	+1 pig	2.9 **
DNN	-1 nipple	4.6 *
DAP	-1 d	0.5 **
DES	-10% survival	11.5 *
DINB	+1% inbreeding	1.5 *

[a] BWT = individual birth weight, DBA = dam's number of pigs born alive, DNN = dam's number of nipples, DAP = dam's age at puberty, DES = dam's embryonic survival at 50 d, DINB = dam's inbreeding coefficient.

[b] A decrease of 10 g from mean BWT (.022 lb) increased the likelihood of splayleg 1.5%, a decrease of 20 g (.044 lb) increased the likelihood by $100*[(1+1.5/100)^2 –1] = 3.02\%$, a 30 g decrease (.066 lb) increased the likelihood by $100*[(1+1.5/100)^3 –1] = 4.57\%$, etc.

*$P < 0.05$.

**$P < 0.01$.

Results and Discussion

The incidence of SL in Lines I, C1 and T across generations is shown in Figure 2. The incidence was consistently greatest in Line T. Until Generation 9, the incidence was less in Line I than Line C1, but after Generation 10, the incidence in Line I relative to Line C1 tended to increase.

The incidence of SL in Lines IOL, COL and C2 is shown in Figure 3. After Generation 10, the difference in percentage of pigs born SL in Line IOL and in Line C2 was 2.6%. The incidence of SL pigs tended to be greater in Line COL than in Line C2 after Generation 10.

Percentage increases in the likelihood of the SL condition for traits significantly associated with it in logistic regression models are in Table 2. Incidence of SL in males was 223.6% greater than in females ($P < 0.01$). Regression coefficients on continuous variables in the model are expressed as the percentage increase in the likelihood of SL per change in the trait as a deviation from the population mean. For example, the logistic regression of incidence of

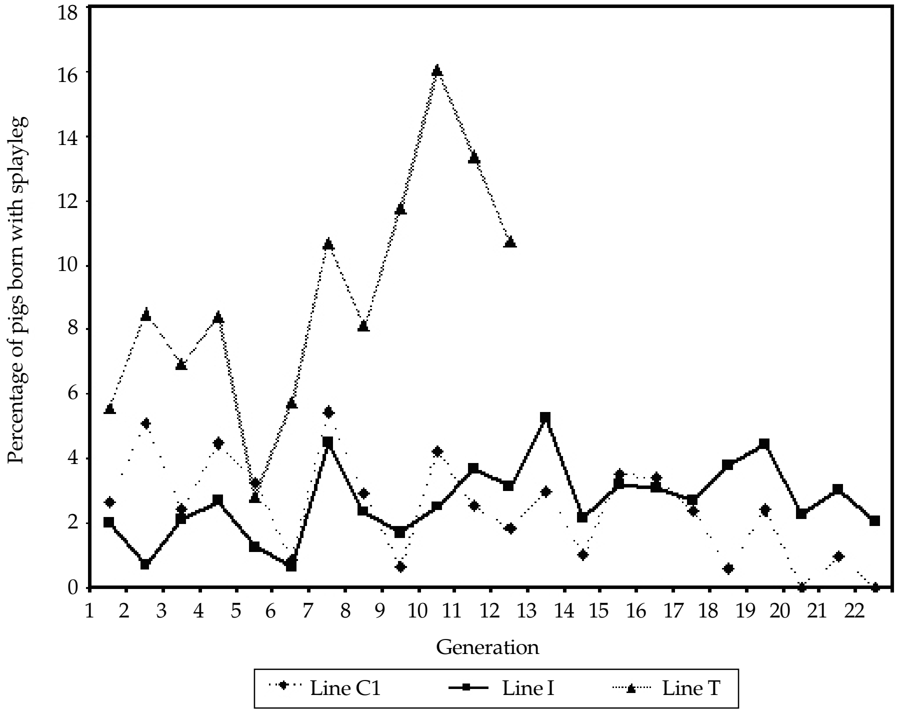

Figure 2. Percentage of pigs born splayleg (SL) by generation in Lines C1, I and T (see footnote to Table 3 for description of lines).

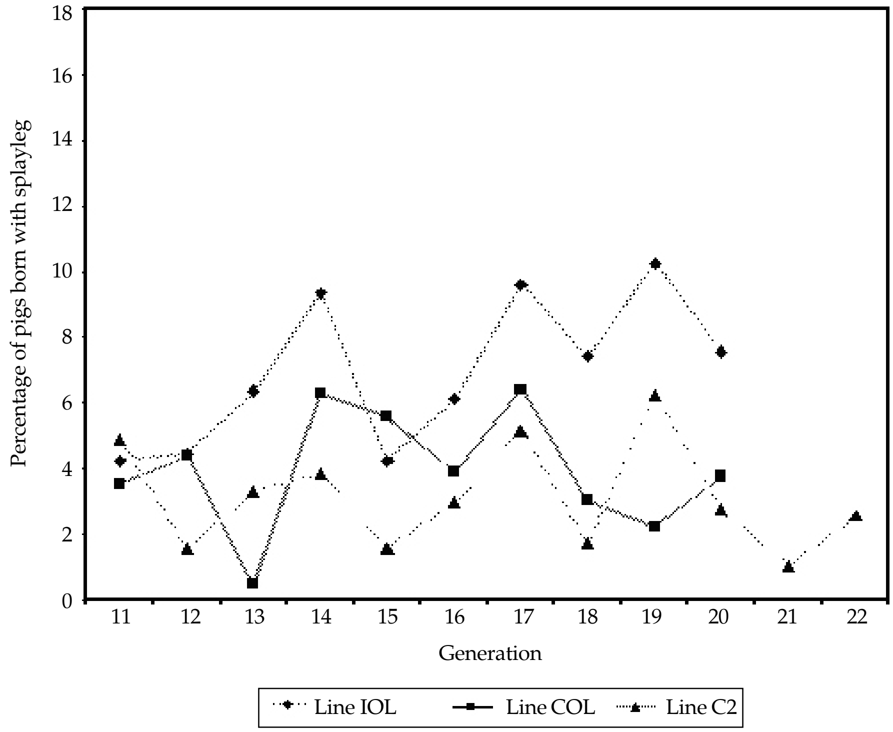

Figure 3. Percentage of pigs born splayleg (SL) by generation in Lines IOL, COL and C2 (see footnote to Table 3 for description of lines).

SL per decrease of 10 g (.022 lb) in BWT was 0.015, interpreted as an increase of 1.5% in the likelihood of SL for a deviation of −10 g from the population mean BWT. Additional deviations from the population mean produced exponential rather than linear increases in the likelihood so that a decrease of 20 g (.044 lb) in BWT increased the likelihood of SL by 100*[(1+1.5/100)^2 −1] = 3.02%, and a 30 g (.066 lb) decrease increased the likelihood by 100*[(1+1.5/100)^3 −1] = 4.57%, etc.

Five traits of the dam significantly affected the likelihood of SL pigs. The percentage of SL pigs increased as litter size increased ($P < 0.01$). In addition, gilts that reached puberty at younger ages ($P < 0.01$) and gilts that had fewer nipples ($P < 0.05$) farrowed litters with a greater incidence of SL pigs. However, age at farrowing did not affect the incidence of SL pigs. Although there was variation in age at puberty, the breeding period was approximately the same time each year for each contemporary group. Gilts were mated to farrow at an average age of one year and in those generations in which age at puberty was recorded, only 3.5% of the gilts were mated at their pubertal estrus or their first post-pubertal estrus. Consequently, age at puberty and age at farrowing are not similar traits. Decreased embryonic survival to 50 days also increased ($P < 0.05$) the probability of SL pigs in the litter. Inbreeding of the pig did not affect the incidence of SL ($P > 0.10$), but the likelihood of the SL condition increased with dam's inbreeding ($P < 0.05$). In other research, it also was found that sows with shorter gestation lengths have litters with greater incidence of SL pigs.

Maternal genetic effects on incidence of SL were more than twice as great as direct genetic effects of the pig. Direct heritability, the proportion of the variation due to effects of the pig's genes, was 0.07; maternal heritability, the proportion of the variation due to effects of the dam's genes, was 0.16. Phenotypic correlations of SL with other traits were close to zero. However, a correlation of 0.32 between maternal genetics for SL and direct

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genetic effects for BA was found.

Table 3. Regression coefficients (b) and standard errors (se) of line genetic and phenotypic values of incidence of splayleg pigs in percentage units[a] on generation number.

	Direct genetic	Maternal genetic	Phenotypic
Line[b]	b + se	b + se	b + se
C1	-0.274 + 0.004	0.188 + 0.005	-0.158 + 0.029
I	-0.003 + 0.003	0.106 + 0.004	0.067 + 0.027
T	0.243 + 0.014	0.527 + 0.024	0.777 + 0.144
IOL	0.121 + 0.012	0.508 + 0.019	0.472 + 0.123
COL	-0.273 + 0.009	0.383 + 0.015	-0.001 + 0.097
C2	0.086 + 0.008	0.113 + 0.012	-0.042 + 0.079

[a] Change in incidence of SL per year, i.e., the phenotypic regression for C1 of -0.158 is a decrease in incidence of SL of .158% per year.

[b] C1 = Randomly selected control line 1, I = Index selection line, T = testis size selection line, IOL = line derived from Line I and subsequently selected for ovulation rate and litter size, COL = line derived from line C1 and subsequently selected for ovulation rate and litter size, and C2 = random selection line 2 derived from line C1.

Annual direct and maternal genetic and phenotypic trends are presented in Table 3. These are estimates of the average observed changes per generation. In addition, genetic parameters were estimated from the data and used to calculate predicted genetic changes in each line to compare them with realized responses. Predicted responses in incidence of SL were calculated from estimates of the responses in litter size in each line and the correlation between direct genetic effects for number of pigs born alive and maternal genetic effects for SL pigs. Predicted maternal genetic responses per generation in percentage units were 0.159, 0.323, -0.068, 0.420, 0.446, and 0.146 for Line C1, I, T, IOL, COL, and C2, respectively. Predictions were relatively close to observed responses in all lines except I and T. Index selection was discontinued in Line I at Generation 12 and selection on number of fully formed pigs was practiced thereafter. From Generation 12 to Generation 22, the realized trend in maternal genetic merit was 0.339 + 0.014 percentage units, which is similar to the predicted trend. While index selection was practiced, maternal genetic trend in SL was suppressed. However, after index selection, realized maternal genetic trend was faster than predicted. Differences between predicted and realized responses in certain lines could also be chance associations due to genetic drift. The large variation in direct genetic trend among lines (Table 3) indicated either no correlated response to litter size selection or genetic drift cancelled the effect of selection.

Splayleg is a heritable trait, subject to both direct and maternal genetic variation. The maternal component is correlated genetically with dam's genetic merit for litter size. Selection to increase litter size is not expected to affect the genetic potential of individual pigs to be born with SL. However, increased genetic potential of sows to create a uterine environment causing SL may occur with selection for increased litter size.

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[1] J. W. Holl is a graduate student and R. K. Johnson is a professor in the Department of Animal Science.