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Estimates of genetic parameters for kyphosis in two crossbred swine populations[1,2]

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ABSTRACT: Genetic parameters for degree of kyphosis were estimated from a Duroc-Landrace F_2 population (n = 316) and from a composite population (line C) composed of Duroc, Large White, and 2 sources of Landrace (n = 1,552). Live presentation did not indicate kyphosis in pigs or sows. Degree of kyphosis was measured by scoring the shape of the vertebral column of split carcasses on a scale from 0 (normal) to 3 (severe). Of the animals slaughtered, 75.6 and 68.9% were normal, 11.1 and 23.3% were mild, 11.1 and 6.2% were moderate, and 2.2 and 1.5% were severe in F_2 and line C, respectively. Fixed effects of age, sex, number of ribs, number of lumbar vertebrae, number of nipples, carcass length, and HCW were not significantly associated ($P > 0.10$) with kyphosis score when using linear models. Estimated heritabilities for kyphosis score were 0.30 and 0.32 in F_2 and line C, respectively, when using an animal model. Estimated genetic correlations between kyphosis score and number of ribs, number of lumbar vertebrae, number of nipples, carcass length, and HCW were 0.05, −0.13, 0.00, 0.05, and 0.03, respectively. Selection to decrease kyphosis should be effective and would not be expected to affect the number of ribs, lumbar vertebrae, nipples, or carcass length. In addition, selection for growth should not affect the incidence of kyphosis.

Key words: heritability, kyphosis, pig

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INTRODUCTION

A visual kyphosis condition in swine has been documented in herds worldwide (Penny and Walters, 1986; Done and Gresham, 1998; Nielsen et al., 2003). The thoracic spine appears concave and the lumbar region is convex, giving a lordosis-kyphosis visual appearance. Pigs have been commonly referred to as "humpy-back," "kinky back," and "dipped shoulder." In addition, research has shown no abnormal characteristics such as neurological problems, metabolic diseases, inflammation, or spinal infections (Nielsen et al., 2005). However, most studies have been done on pigs between 3 and 16 wk of age. Most pig husbandry practices suggest disposing of severely affected piglets (Penny and Walters, 1986; Done et al., 1999). Consequently, this condition has rarely been observed in breeding herds (Penny and Walters, 1986).

A kyphotic condition also has been observed in pork carcasses from 2 experimental lines. Pigs reached slaughter weight with minimal visual evidence of a kyphotic condition. However, a degree of kyphosis was observed in split carcasses. Furthermore, carcasses from sows were observed with the kyphotic condition.

Kyphosis has the potential to be problematic during pork fabrication. If structural abnormalities are present, primals and subprimals may not meet specifications and make deboning efforts challenging. Therefore, structural abnormalities may decrease the value of a pork carcass, especially when they involve the loin. The objective of this study was to identify variables associated with degree of kyphosis and to estimate genetic parameters between the condition and other structural traits.

MATERIALS AND METHODS

All animal procedures were reviewed and approved by the US Meat Animal Research Center (**USMARC**) Animal Care and Use Committee.

Animals

A 3-generation F_2 population was developed by mating purebred Duroc and Landrace pigs. Pigs were raised at a commercial production site under standard

[1]Mention of a trade name, proprietary product, or specified equipment does not constitute a guarantee or warranty by the USDA and does not imply approval to the exclusion of other products that may be suitable.

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commercial production conditions. At approximately 114 kg, pigs were sent on 8 slaughter dates to a commercial slaughter facility where they were electrically stunned and processed. The left loin of each carcass was removed at 24 h postmortem and delivered to the USMARC for evaluation. Additional details of this population were reported by Rohrer et al. (2006). A total of 316 F_2 pigs were studied.

A composite population (line C) was developed at USMARC. Twelve Landrace and 12 Duroc males were selected from commercially available pigs. Each sire within breed was arbitrarily assigned a sire code of 1 to 12. Semen from these boars was used to inseminate females (n = 220) from a Yorkshire-Landrace composite population developed at USMARC. One son and 10 daughters from each boar were randomly selected to produce the next generation. The second generation was formed by breeding Landrace-sired animals to Duroc-sired animals. Matings of gilts from a sire code were made to a boar from the corresponding sire code of the opposite breed. Selection of parents in subsequent generations was based on sire code, where 1 boar and 20 gilts from each sire were selected. Matings were random, except paternal half-sib matings were avoided. Pigs were produced in 4 farrowing seasons annually. Boars were selected from the first season and used across all seasons. Two seasons farrowed gilts and 2 seasons farrowed second-parity sows and a smaller, varied number of gilts. Approximately 120 litters were produced each season. Animals used for this study were born in generations 1, 3, 4, 5, and 6.

All animals in line C were raised and slaughtered at the USMARC. Animals were electrically stunned and processed following industry standards. Pigs were slaughtered at approximately 107 kg of live BW and in groups of approximately 21 pigs. Sows were sent to slaughter in groups of approximately 13 sows. A total of 53 and 39 groups of pigs and sows, respectively, were evaluated.

Data

To measure the kyphosis condition, a subjective back score (**BS**) was given for each evaluated spine. Four categories were used: normal (0), mild (1), moderate (2), and severe (3). Mild was defined as a slight convex curvature of vertebrae only. Moderate was defined as a convex curvature in the vertebrae and spinal chord. Severe was defined as an extreme convex curvature of the vertebrae and spinal chord. Examples are shown in Figure 1. Number of ribs (**RIB**), number of lumbar vertebrae (**LV**), number of nipples (**NN**), carcass length (**CL**), and HCW were also recorded in line C.

Statistical Procedures

The BS measured in line C was initially analyzed with a general linear model by using the GLM procedure (SAS Inst. Inc., Cary, NC) to determine associated fixed-effect variables. Initially, herd status (pig or sow) was found to be nonsignificant ($P = 0.33$). Back score data for pigs and sows were treated as one trait and tested for possible interactions with other variables. No interactions were significant ($P > 0.10$). Therefore, BS data for pigs and sows were combined in subsequent analyses.

Genetic parameters were estimated with an animal model by using the REMLf90 program (Misztal, 2002). Models were derived from the following linear animal model:

$$y = X\beta + Za + e,$$

where y represents the vector of observations, X and Z are known design matrices, β represents the vector of fixed effects, a is the vector of random additive genetic effects, and e is the vector of random residual effects. Expectations and variances of random variables are as follows:

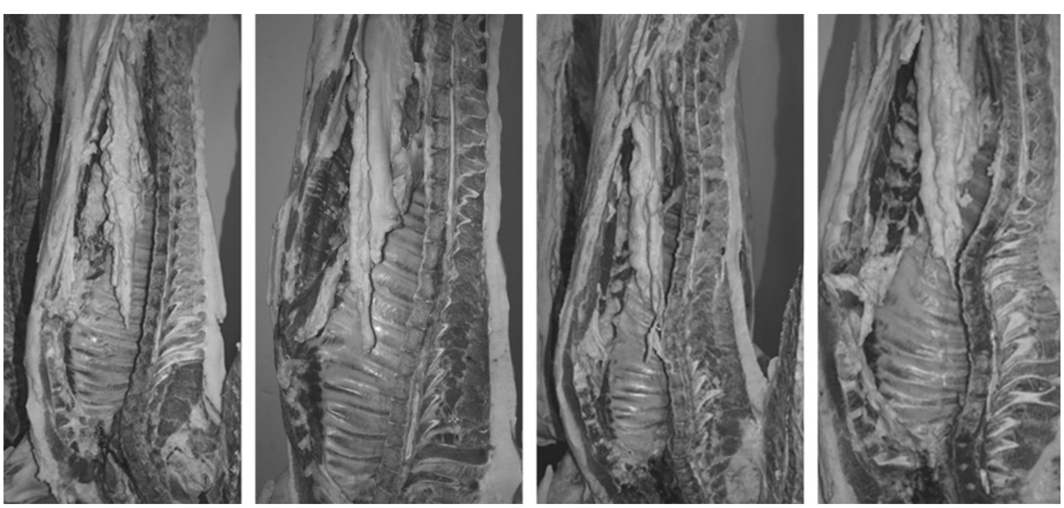

Figure 1. Carcasses, from left to right, scored normal, slight, moderate, and severe for kyphosis.

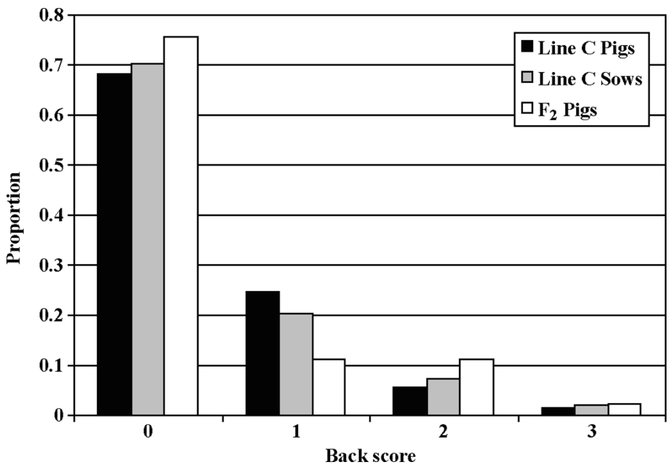

Figure 2. Distribution of back scores for market pigs and cull sows.

$$E\begin{bmatrix} a \\ e \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$V\begin{bmatrix} a \\ e \end{bmatrix} = \begin{bmatrix} G \otimes A & 0 \\ 0 & R \otimes I \end{bmatrix},$$

where $\otimes$ denotes a direct product operation; G and R are additive genetic and residual covariance matrices, respectively, with order equal to the number of traits in the analysis; A is the numerator relationship matrix; and I is an identity matrix of appropriate order.

In line C, 2-trait analyses were done, with BS paired with RIB, LV, NN, CL, and HCW. In the F_2 population, BS was analyzed in a single-trait model. Fixed effects fitted in the model for BS included slaughter group and sex. The RIB, LV, and NN models included the fixed effects of sex and birth season. Slaughter group and sex were fitted as fixed effects in addition to fitting the covariates of age for HCW and HCW for CL. A random common litter environmental component for BS was not significant.

Table 2. Line C estimates of heritability (h^2), phenotypic variances (σ^2), genetic correlations (r_g), and phenotypic correlations (r_p) from 2-trait analyses

Trait[1]	h^2	σ^2	BS r_g	BS r_p
BS	0.32	0.44	—	—
RIB	0.88	0.38	0.05	0.03
LV	0.26	0.17	−0.13	−0.05
NN	0.39	1.00	0.00	−0.05
CL	0.86	5.35	0.05	0.05
HCW	0.26	10.10	0.03	0.01

[1]BS = back score; RIB = number of ribs; LV = number of lumbar vertebrae; NN = number of nipples; CL = carcass length, cm; and HCW, kg.

RESULTS

Distributions of BS in market pigs and cull sows were similar and are shown in Figure 2. On average, 68.9% were classified as normal, 23.3% as mild, 6.2% as moderate, and 1.5% as severe in line C. In the F_2 population, 75.6% of pigs were classified as normal, 11.1% as mild, 11.1% as moderate, and 2.2% as severe. Raw means, minima, maxima, data counts, and phenotypic variances are presented in Table 1.

Estimates of genetic parameters are given in Table 2. Estimates of heritability for BS were 0.30 in F_2 and 0.32 in line C. In line C, heritabilities for other traits ranged from 0.26 to 0.88. No strong genetic or phenotypic associations existed between BS and RIB, BS and LV, BS and NN, BS and CL, or BS and HCW.

DISCUSSION

Kyphosis incidence rates of as great as 4% have been reported in other countries (Penny and Walters, 1986; Done and Gresham, 1998; Nielsen et al., 2003). In addition, Done et al. (1999) and Corradi et al. (2004) reported extreme incidence rates of 30 to 40% in some herds. Done et al. (1999) and Laitat et al. (2006) suggested a genetic control. However, Penny and Walters (1986), Lahrmann and Hartung (1993), and Nielsen et al. (2005) suggested a spontaneous, nongenetic control. Furthermore, it has been identified in purebred and crossbred pigs and in pigs from the Landrace, Large

Table 1. Phenotypic mean, minimum, maximum, and variance for back score, number of ribs, number of lumbar vertebrae, nipple number, carcass length, and HCW[1]

Trait	Line[2]	Pigs	Sows	Mean	Minimum	Maximum	σ^2
BS	F_2	316	0	0.40	0	3	0.60
BS	C	1,039	513	0.40	0	3	0.46
RIB	C	763	533	15.37	14	17	0.38
LV	C	761	533	6.12	5	7	0.17
NN	C	3,909	0	14.48	10	20	1.06
CL	C	1,093	0	82.39	75.0	90.0	6.61
HCW	C	1,094	0	80.40	62.1	100.7	19.99

[1]BS = back score; RIB = number of ribs; LV = number of lumbar vertebrae; NN = number of nipples; CL = carcass length, cm; and HCW, kg.

[2]F_2 = line cross of Duroc and Landrace; C = composite line with Duroc, Landrace, and Yorkshire.

White, Hampshire, and Pietrain swine breeds (Penny and Walters, 1986).

The incidence of kyphosis in pigs has been studied but is not completely understood. Research has not shown any abnormal characteristics, such as neurological problems, metabolic diseases, inflammation, or spinal infections. Evidence of the condition has been reported only after 5 wk of age (Nielsen et al., 2005). Kyphosis in pigs has been associated with the human spinal condition called Scheuermann's disease, which is not present at birth but develops later in childhood (Lowe, 1990). Pathological evidence has shown a lack of vascularization in cartilage tissue in the vertebrae. Nielsen et al. (2005) suggested this lack of development led to misshapen vertebrae. Lahrmann and Hartung (1993) identified congenital malformation, traumatic lesion, inflammation, bone disease, or abnormal body posture in response to chronically painful diseases caused by the formation of these wedge-shaped vertebrae. In addition, rapid overall growth (Penny and Walters, 1986), confinement housing (Penny and Walters, 1986; Berner et al., 1990), and abnormal dorsal spinal muscle growth (Done and Gresham, 1998) have been hypothesized as causative agents or have been associated with kyphosis.

The kyphotic condition studied herein may or may not be the same condition studied previously. Although pathological abnormalities were not observed or measured, growth rate was not associated with the incidence. Studies by Penny and Walters (1986) and Done and Gresham (1998) also reported no adverse effects on growth. In addition, age was not identified as a factor. Weight and age were associated with degree of kyphosis in studies by Nielsen et al. (2005). However, only 22 pigs were studied and they ranged in BW from 5.2 to 75 kg. The current study used older, heavier pigs and sows. Age and BW may not have been significant if kyphotic development was completed in market pigs and sows. In addition, earlier studies have focused on live pigs with an observable kyphotic condition. The current study identified kyphosis in carcasses where live observation had not indicated strong evidence for kyphosis.

Kyphosis has been measured by various methods. In live animals, it has been measured as a binary trait. After observing the incidence in live animals, Nielsen et al. (2005) developed a method to measure the degree of kyphosis on the carcass by using trigonometry. Laitat et al. (2006) measured angles with the Cobb method in lateral spinal radiographs. These methods provide objective quantitative measurements. Done and Gresham (1998) provided a subjective visual scoring measurement on live animals. These scores produced a lower incidence rate than identified in the current study. The scoring done in this study was subjective, relatively quick, and easy; however it could be measured only on carcasses. The structural traits of RIB, LV, NN, and CL were measured as possible indicators. However, none had strong genetic or phenotypic associations with kyphosis.

After considering the variance components, it was concluded that a heritable genetic component existed in both populations. The study by Laitat et al. (2006) confirmed this conclusion by associating the degree of kyphosis in pigs from planned matings of kyphotic and normal boars and sows. This is in contrast to hypotheses by Lahrmann (1990), Lahrmann and Hartung (1993), and Nielsen et al. (2005), possibly because of the size of experiments or differences in the definition of the trait. In addition, these previous studies considered only the extreme condition, in which kyphosis was observable in live pigs. Treating kyphosis as a binary trait in which only the extreme observations were considered kyphotic, the estimated heritabilities were 0.02 and 0.03 in line C and the F_2 population, respectively, when using the data herein. Therefore, the gradient of the scoring method may provide more information about kyphosis. Although production practices may dispose of extreme kyphotic phenotypes, a less extreme kyphosis may go unnoticed and may be maintained, decreased, or increased because of genetic drift. However, selection against kyphosis as defined in this study could decrease the degree of kyphosis in a population. In addition, the lack of genetic association with HCW indicates that selection for growth may not negatively affect the kyphotic condition in a population.

In conclusion, subjective scoring of spines in carcasses of market-weight pigs and cull sows indicated kyphosis may be in swine herds, although extreme visual cases were not observed in live animals. Kyphosis is fully developed before pigs reach market weight. In addition, kyphosis exhibits genetic variation and is not correlated with growth. Therefore, genetic selection against kyphosis should be effective and should not have negative impacts on growth.

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