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Summary and Implications

The purpose of this study was to estimate the heritabilities and genetic correlations for body composition and structural soundness traits using 1449 gilts in a commercial sow unit. Evaluated body composition traits included body weight, loin muscle area, last rib backfat and 10th rib backfat. Soundness traits consisted of 6 body structure traits, 5 leg structure traits per leg pair and overall leg action. Variance components were estimated using multivariate animal models. The heritability estimates for body composition traits were high, moderate for body size traits, low to moderate for body shape traits and relatively low for leg traits. Across all evaluated traits, only the heritability estimates for turned front legs did not differ significantly from zero. Several high genetic correlations were obtained among the body structure trait group. The majority of genetic correlations between leg structure traits were low and statistically insignificant. The genetic correlations between leg traits and overall leg action were not significant. However, there was a trend for structural defects being related to poorer overall leg action. The genetic correlations between structure traits and body composition traits were primarily low to moderate indicating that even in a case of antagonistic relationship it is possible to achieve genetic improvement in both composition and structural traits. The fact that non-zero heritability estimates were obtained for almost all studied traits warrants further investigations regarding associations of soundness traits with reproductive performance and sow productive lifetime.

Introduction

Poor sow longevity has both economic and welfare ramifications for the commercial swine industry. On the basis of PigCHAMP ™ reports, between years 1998 and 2006 the average culling frequency of breeding herd females in U.S. commercial swine herds has been 44.6 % and sow mortality rate has been 7.5 %. Lower replacement rates would not only improve the outlook for the swine industry, but also increase the profitability of pork producers in terms of reduced replacement gilt expenses and associated development, isolation and acclimation costs. Furthermore, reduction in the number of gilt litters would improve herd productivity, since gilt litters tend to be smaller and have greater nursery and finisher mortality and poorer nursery and finisher average daily gain.

Reproductive failure and feet and leg problems are the primary culling reasons for young sows. Maintaining acceptable reproduction rates in younger females and selecting structurally sound females as replacements are therefore important factors in increasing sow productive lifetime. Structural defects can lead to impaired welfare, which weakens reproductive performance. Sow with poor legs might expose piglets to greater risk of getting stepped or laid on.

The objective of this study was to estimate the heritabilities for body composition, body conformation and leg soundness traits and genetic correlations both within these trait groups and between body composition and structural traits in commercial gilts. The long term goal of this on going project is to follow the females from entry to a commercial swine unit until culling at the end of their productive life. This will allow for the determination of factors that are associated with superior sow longevity.

Materials and Methods

This study was conducted at a commercial unit and involved 1449 animals entering the herd between October 2005 and July 2006. The gilts were from two commercial genetic lines, 462 animals belonging to a grandparent maternal line and 987 to a parent maternal line. They were progeny of 58 known sires and 836 dams. Sire information was not available for 52 animals. Composition and structural evaluation was carried out on 14 separate dates, and the gilts averaged 124 ± 11 kg body weight and 190 ± 7 days age at the time of appraisal.

Evaluated body composition traits included body weight, and ultrasonically measured loin muscle area, last rib backfat and 10th rib backfat. Ultrasonic images were taken with a Pie Medical 200 (Classic Medical Supply, Inc., Tequesta, FL) by a single technician who was certified by the National Swine Improvement Federation (Bates and Christian, 1994). Soundness traits consisted of 6 body structure traits; body size (length, depth, width) and body shape (hip structure, rib shape, correctness of top line), 5 leg structure traits per leg pair; front legs (legs turned, buck knees, pastern posture, foot size, uneven toes) and rear legs (legs turned, weak/upright legs, pastern posture, foot size, uneven toes) and overall leg action. Overall leg action reflects both structural soundness and freedom of other defects or diseases affecting the gait. All soundness traits were independently evaluated by two experienced scorers using a 9 point scale. Correctness of top line, turned front legs, turned rear legs and weak/upright rear legs were each cut into two traits prior to analyzing.

Variance components were estimated with multivariate animal models using the AI-REML algorithm in the DMU-package (Madsen and Jensen, 2004). The statistical model for last rib backfat, 10th rib backfat and loin muscle area included gilt line and evaluation day as fixed effects, animal as a random effect and body weight at evaluation as a covariate. The model used for analyzing body weight was as previous, but age at evaluation was included as a covariate. Soundness traits were analyzed with an identical model as which backfat and loin muscle area were, except scorer was included as an additional fixed effect.

Results and Discussion

The heritabilities of body composition traits were high (Table 1), body weight having the lowest (0.51) and last rib backfat the highest estimate (0.72). The genetic correlation between the two backfat measurements was very high and their genetic correlations with loin muscle area ranged from -0.32 to -0.24. The phenotypic correlations within body composition trait group had high resemblance to the corresponding genetic correlations.

Traits indicating body size had moderate heritability estimates ranging between 0.25 and 0.34 (Table 2). The genetic correlations between these traits were high. Increased body length decreased both body depth and width. Greater body depth was associated with greater body width. Heritability estimates for body shape traits were low to moderate ranging from 0.11 to 0.26. High top line was significantly associated with steep hip and flat rib shape. Weak top line had opposite relationships with the fore mentioned traits even though the genetic correlation with hip structure was not significant. High top line and flat rib shape were genetically closely related to increased body length and reduced body depth and width.

Among leg traits, the highest heritability estimates were obtained for front and rear pastern postures (0.28 – 0.31). The remaining front leg traits had heritability estimates ranging from 0.02 to 0.16, and heritability estimates for rear leg traits ranged between 0.12 and 0.21 (Tables 3 and 4). The estimates for front legs turned out or in did not differ significantly from zero. This was likely the result of relatively little variance for the trait especially when considering front legs turned in. Overall leg action had a heritability of 0.12. The majority of genetic correlations between leg structure traits were low and they were rarely significant. The only significant genetic correlation within front leg traits was found between pastern posture and foot size. Upright pastern posture, small foot size and uneven toes were mutually correlated both within front and rear legs. On the other hand, weak pasterns, larger foot size and evenly sized toes were associated with each other. Regardless of the leg pair, there was an insignificant association between legs turned in and greater front toe size difference, whereas legs turned out was related to more evenly sized toes. Weak rear legs were genetically closely correlated with weak rear pastern posture and larger foot size. Correspondingly, upright rear legs were correlated with upright pasterns and smaller foot size. Although only upright front pasterns impaired overall leg action significantly, a weak trend of structural defects being related to impaired overall leg action could be seen in the genetic correlations. Legs turned in, pastern postures and foot sizes of the two leg pairs had positive correlations (Table 5). Buck knees were significantly associated with outwardly turned rear legs and upright posture of rear legs and rear pasterns.

Long and shallow bodied gilts tended to have less backfat and smaller loin muscle area than shorter and deeper bodied gilts (Table 6). Body width had a high favorable genetic correlation with loin muscle area. Furthermore, larger loin muscle area was associated with level hip structure and ribs having more shape. Legs turned out, buck knees, weak rear legs and upright pasterns seemed to be related to lower backfat thickness, even though the only significant genetic correlation was obtained between backfat and front pastern posture. In contrast, front legs turned in, weak pasterns and uneven toes were related to higher backfat thickness. Greater loin muscle area was associated with rear legs turned in, more upright rear legs and upright pastern posture. Overall leg action was significantly correlated with backfat measurements, so that animals having thicker backfat layer had better movements.

The heritabilities of body structure traits were primarily higher than the heritability estimates of leg structure traits. Therefore, genetic improvement in body structure traits would likely be faster than what could be achieved in leg structure traits. The relatively low heritability of overall leg action might be explained by the varying problems behind impaired movements, some having genetic background and others caused by environmental factors. The genetic correlations between structure traits and body composition traits were primarily low to moderate. Thus even in a case of antagonistic relationship it is possible to achieve genetic improvement in both composition and structural traits. Across all evaluated traits, only the heritability estimates for turned front legs did not differ significantly from zero. The fact that non-zero heritability estimates were obtained for all other traits warrants further investigations regarding associations of soundness traits with reproductive performance and sow productive lifetime.

Table 1. Heritabilities of the body composition traits (on the diagonal) and their genetic correlations (above the diagonal) and phenotypic correlations (below the diagonal).

Body composition	1	2	3
1. Last rib backfat	**0.72 ± 0.09**	0.96 ± 0.01	-0.24 ± 0.11
2. 10th rib backfat	0.86	**0.65 ± 0.09**	-0.32 ± 0.11
3. Loin muscle area	-0.22	-0.27	**0.60 ± 0.08**

Table 2. Heritabilities of the body structure traits (on the diagonal) and their genetic correlations (above the diagonal) and phenotypic correlations (below the diagonal).

Body structure	1	2	3	4	5	6	7
1. Body length	**0.29 ± 0.07**	0.92 ± 0.07	-0.80 ± 0.11	-0.09 ± 0.25	0.88 ± 0.17	0.35 ± 0.21	0.84 ± 0.09
2. Body depth	0.42	**0.34 ± 0.08**	-0.77 ± 0.10	-0.15 ± 0.25	0.80 ± 0.17	0.10 ± 0.22	0.74 ± 0.10
3. Body width	-0.30	-0.44	**0.25 ± 0.07**	0.57 ± 0.23	-0.90 ± 0.19	-0.36 ± 0.22	-0.93 ± 0.07
4. Weak top line	-0.07	-0.07	0.10	**0.11 ± 0.05**	-0.48 ± 0.26	-0.31 ± 0.26	-0.57 ± 0.22
5. High top line	0.13	0.15	-0.15	-0.21	**0.12 ± 0.05**	0.63 ± 0.21	0.92 ± 0.15
6. Hip structure	0.00	0.01	-0.06	-0.09	0.28	**0.18 ± 0.06**	0.45 ± 0.20
7. Rib shape	0.38	0.46	-0.45	-0.11	0.20	0.11	**0.26 ± 0.07**

Table 3. Heritabilities of the front leg structure traits (on the diagonal) and their genetic (above the diagonal) and phenotypic correlations (below the diagonal).

Front leg structure trait	1	2	3	4	5	6	7
1. Front legs turned out	**0.06 ± 0.04**	-0.81 ± 0.57	-0.37 ± 0.40	0.23 ± 0.34	0.29 ± 0.36	-0.54 ± 0.45	0.42 ± 0.40
2. Front legs turned in	-0.24	**0.02 ± 0.03**	0.17 ± 0.55	-0.07 ± 0.48	0.05 ± 0.51	0.35 ± 0.58	-0.44 ± 0.57
3. Buck knees	0.04	0.03	**0.13 ± 0.05**	0.18 ± 0.25	-0.31 ± 0.28	-0.13 ± 0.33	0.45 ± 0.25
4. Pastern posture	-0.05	0.03	0.26	**0.28 ± 0.08**	0.59 ± 0.17	0.35 ± 0.25	0.83 ± 0.12
5. Front foot size	-0.01	0.06	-0.00	0.27	**0.16 ± 0.06**	0.20 ± 0.29	0.38 ± 0.25
6. Uneven front toes	0.02	0.04	0.03	0.11	0.13	**0.09 ± 0.04**	0.01 ± 0.33
7. Overall leg action	0.04	-0.01	0.31	0.40	0.11	0.09	**0.12 ± 0.05**

Table 4. Heritabilities of the rear leg structure traits (on the diagonal) and their genetic (above the diagonal) and phenotypic correlations (below the diagonal).

Rear leg structure trait	1	2	3	4	5	6	7	8
1. Rear legs turned out	**0.17 ± 0.07**	-0.88 ± 0.15	0.30 ± 0.29	-0.07 ± 0.26	-0.03 ± 0.24	0.10 ± 0.28	-0.38 ± 0.27	0.35 ± 0.28
2. Rear legs turned in	-0.27	**0.14 ± 0.05**	-0.26 ± 0.28	0.16 ± 0.26	0.31 ± 0.23	0.01 ± 0.28	0.44 ± 0.26	0.03 ± 0.30
3. Weak rear legs	0.14	0.00	**0.14 ± 0.06**	-0.83 ± 0.15	-0.76 ± 0.15	-0.79 ± 0.23	-0.01 ± 0.31	0.24 ± 0.30
4. Upright rear legs	-0.03	0.02	-0.43	**0.21 ± 0.07**	0.77 ± 0.12	0.68 ± 0.22	-0.03 ± 0.28	0.29 ± 0.27
5. Rear pastern posture	0.05	-0.02	-0.35	0.43	**0.31 ± 0.08**	0.82 ± 0.15	0.12 ± 0.25	0.27 ± 0.24
6. Rear foot size	0.03	-0.01	-0.07	0.12	0.27	**0.13 ± 0.05**	0.27 ± 0.29	-0.03 ± 0.31
7. Uneven rear toes	-0.08	0.02	0.01	0.02	0.03	0.04	**0.12 ± 0.05**	0.12 ± 0.31
8. Overall leg action	0.19	0.01	0.23	0.07	0.16	0.11	0.11	**0.12 ± 0.05**

Table 5. Genetic correlations (± s.e.) between front and rear leg structure traits.

	Front leg trait[a]					
Rear leg trait[b]	FLTO	FLTI	BK	FPP	FFS	UFT
RLTO	0.06 ± 0.37	-0.49 ± 0.49	0.48 ± 0.24	0.33 ± 0.21	0.33 ± 0.24	0.26 ± 0.31
RLTI	0.14 ± 0.36	0.43 ± 0.52	-0.51 ± 0.25	0.31 ± 0.24	0.29 ± 0.26	-0.06 ± 0.32
WRL	0.66 ± 0.35	-0.46 ± 0.54	-0.53 ± 0.29	-0.03 ± 0.27	-0.07 ± 0.30	0.13 ± 0.33
URL	-0.40 ± 0.31	0.15 ± 0.48	0.52 ± 0.24	0.37 ± 0.21	0.17 ± 0.25	0.04 ± 0.29
RPP	-0.17 ± 0.33	0.25 ± 0.56	0.51 ± 0.23	0.43 ± 0.17	0.38 ± 0.21	0.09 ± 0.27
RFS	-0.15 ± 0.38	0.46 ± 0.64	0.21 ± 0.30	0.42 ± 0.22	0.72 ± 0.17	0.01 ± 0.31
URT	-0.26 ± 0.38	0.71 ± 0.55	0.30 ± 0.29	0.31 ± 0.24	-0.02 ± 0.28	-0.03 ± 0.33

[a]FLTO = front legs turned out, FLTI = front legs turned in, BK = buck knees, FPP = front pastern posture, FFS = front foot size, and UFT = uneven front toes.
[b]RLTO = rear legs turned out, RLTI = rear legs turned in, WRL = weak rear legs, URL = upright rear legs, RPP = rear pastern posture, RFS = rear foot size, and URT = uneven rear toes.

Table 6. Genetic correlations (± s.e.) between body composition and soundness traits.

	Body composition trait		
Soundness trait	Last rib backfat	10th rib backfat	Loin muscle area
Body length	-0.57± 0.12	-0.51 ± 0.13	-0.35 ± 0.14
Body depth	-0.58 ± 0.11	-0.48 ± 0.12	-0.43 ± 0.13
Body width	0.18 ± 0.14	0.07 ± 0.15	0.79 ± 0.09
Weak top line	0.04 ± 0.21	-0.00 ± 0.22	0.25 ± 0.21
High top line	-0.32 ± 0.18	-0.32 ± 0.18	-0.37 ± 0.19
Hip structure	0.12 ± 0.18	0.11 ± 0.18	-0.37 ± 0.17
Rib shape	-0.25 ± 0.14	-0.20 ± 0.15	-0.57 ± 0.13
Front legs turned out	-0.31 ± 0.29	-0.28 ± 0.29	-0.14 ± 0.27
Front legs turned in	0.86 ± 0.35	0.75 ± 0.41	0.00 ± 0.34
Buck knees	-0.10 ± 0.20	-0.11 ± 0.21	-0.06 ± 0.20
Front pastern posture	-0.31 ± 0.15	-0.26 ± 0.16	0.19 ± 0.16
Front foot size	-0.04 ± 0.18	0.01 ± 0.19	-0.02 ± 0.19
Uneven front toes	0.36 ± 0.21	0.37 ± 0.21	-0.13 ± 0.21
Rear legs turned out	-0.13 ± 0.19	-0.31 ± 0.18	-0.45 ± 0.16
Rear legs turned in	-0.14 ± 0.19	-0.01 ± 0.20	0.49 ± 0.17
Weak rear legs	-0.17 ± 0.20	-0.24 ± 0.21	-0.40 ± 0.19
Upright rear legs	0.10 ± 0.17	0.08 ± 0.18	0.29 ± 0.16
Rear pastern posture	-0.17 ± 0.15	-0.13 ± 0.15	0.49 ± 0.13
Rear foot size	0.23 ± 0.19	0.23 ± 0.20	0.26 ± 0.19
Uneven rear toes	0.30 ± 0.20	0.35 ± 0.21	0.20 ± 0.19
Overall leg action	-0.54 ± 0.18	-0.52 ± 0.19	0.14 ± 0.20

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