Heritability Estimates for Conformation Traits in Pigs

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Summary

Data from 1006 pigs selected for breeding and subsequently scored at 22-24 weeks of age were used to estimate heritabilities for conformation traits. Front wrists, front pasterns, back hocks, back pasterns, front view, rear view and back shape were each subjectively scored by a single operator. For the individual traits heritability estimates ranged from high (0.42±0.09 for front pasterns) to negligible (0.01±0.04 for back hocks and body shape). Results suggest that at least some individual conformation traits (eg. front wrists and pasterns; back pasterns) would respond to selection, whereas other conformation traits (eg. hocks, front and rear views, or shape) are less likely to.

Traits combining conformation scores exhibited low to moderate heritabilities, but also lower variances. Heritabilities estimated for combined wrist and front pastern scores, combined hock and back pastern scores, or combined leg scores overall were 0.35±0.08, 0.10±0.06 and 0.30±0.08, respectively. A binary trait summarising the incidence of injuries was moderately (linear methods) to highly heritable 0.42±0.20 (generalised linear methods).

Week off test, sex, performance test system and breed affected conformation scores in diminishing order, but overall explained relatively little variation (generally R^2<3-5%). Variation in finishing weight, average daily gain, eye muscle depth or backfat further explained relatively little of the variation in conformation scores (additional R^2<1-2%).

Data were poorly structured to separate additive genetic from common litter effects.

Introduction

Independent culling for poor conformation in nucleus breeding herds results in a reduced response to selection for traits explicitly included in the breeding objective. In addition, subjective phenotypic evaluations that lead to animals being culled for poor conformation generally do not account for systematic effects influencing the animals' appearance. Assessing the relative influence of genetic and non-genetic effects on conformation traits can determine whether culling on conformation traits could improve future herd conformation, providing a positive outcome that could partially offset losses in the otherwise defined breeding objective. The aim of this study was to assess whether aspects of conformation, for which animals with less desirable characteristics are often culled, are heritable.

Materials and Methods

Conformation traits were scored for 1006 animals selected for breeding between May and September 2002 at QAF Meat Industries (QAF). Traits were scored on both male and female pigs from five lines immediately following performance testing, and conformation was not considered prior to this point. Front wrists (FW), front pasterns (FP), back hocks (BH), back pasterns (BP), front view (FV), rear view (RV) and back shape (BS) were each subjectively scored by a single scorer (Table 1). Injuries were recorded for those animals having correct conformation but displaying signs of injury. These records were re-assigned to the "Correct" conformation class for analyses.

The original scores of 6 and 7 for front and rear views were not consistent with a continuous scoring system, and new categorical variables were created from these scores. The new front (FVNEW) and rear (RVNEW) view traits were created to reflect whether an animal was standing outwards slightly (1), heavily (2) or not at all (0). Binary traits were generated from the scores by combining information across traits. These included: INJ (injured (1) or not (0) on any leg); COR_L (legs all correct (1) or not (0)); and COR_B (body shape (back shape + FVNEW + RVNEW) all correct (1) or not (0)). In addition, parameter estimates were obtained for the averages of combined front leg scores (wrist and front pastern), combined back leg scores (hock and back pastern), and combined leg scores overall.

Table 1 Scoring systems used for conformation traits (Stdg Out: standing out)

	Score						
	1	2	3	4	5	6	7
Score intensity	Heavily	Slightly	Correct	Slightly	Heavily		
Front Wrists	Buckled	Buckled	Correct	Sickled	Sickled	Injured	
Front Pasterns	Straight	Straight	Correct	Weak	Weak	Injured	
Back Hocks	Steep	Steep	Correct	Sickled	Sickled	Injured	
Back Pasterns	Straight	Straight	Correct	Weak	Weak	Injured	
Score intensity	Heavily	Slightly	Correct	Slightly	Heavily	Slightly	Heavily
Front view	X-shaped	X-shaped	Correct	O-shaped	O-shaped	Stdg Out	Stdg Out
Rear view	X-shaped	X-shaped	Correct	O-shaped	O-shaped	Stdg Out	Stdg Out
Back shape	Weak	Correct	Dipped	Arched			

Systematic effects were investigated and estimates of genetic parameters were obtained using ASREML (Gilmour *et al*., 1999). The initial model contained week off test and testing system (electronic feeder versus finisher pens, both with concrete slatted flooring) along with line and sex (fitted as class effects nested within testing system) as fixed effects. Linear regressions for age at selection, end of test weight or lifetime daily gain (ADG), and the performance traits (EMD: eye muscle depth; AVFAT: average backfat) were evaluated within testing system. Models for each trait were subsequently reduced in a stepwise fashion to retain only significant ($P<0.05$) effects. However, week off test and performance testing system were always retained in the final models for parameter estimation, since groups of animals from each test procedure were evaluated separately.

Parameter estimates for the categorical traits were obtained under an animal model, implying approximate normality of scores. Estimates of genetic parameters for binary traits were obtained using generalised linear model procedures, using a probit link function under a sire model (Gilmour *et al.*, 1999). Due to the low number of animals scored per litter, data were generally not adequately structured to separate additive genetic from common environmental (litter) effects.

Results and Discussion

Of the original 1006 records, 950 were retained for analyses after removing progeny data for sires with less than five progeny scored. This editing was performed to reduce the level of uninformative sire progeny means for the binary traits. The edited data contained progeny of 59 sires and 461 dams (Table 2). Mean values and ranges for both conformation and performance traits were almost identical for the original and edited data sets.

Table 2 Number of animals present in each scoring category, raw data means and coefficients of variation (CV) for conformation traits

Trait	Score							Raw Data	
	0	1	2	3	4	5	Total	Mean (SD)	CV (%)
FW	-	19	324	563	44	0	950	2.67 (0.59)	22
FP	-	1	6	523	332	88	950	3.52 (0.67)	19
BH	-	5	135	637	170	3	950	3.03 (0.59)	19
BP	-	3	119	718	107	3	950	2.99 (0.52)	17
FV	-	1	28	648	0	0	677	2.95 (0.21)	7
FVNEW	677	264	9	-	-	-	950	0.31 (0.48)	157
RV	-	3	92	762	2	0	859	2.89 (0.34)	12
RVNEW	859	87	4	-	-	-	950	0.10 (0.31)	316
BS	-	0	937	11	1	-	949	2.01 (0.12)	6
Injured*	852	98	-	-	-	-	950	0.10 (0.30)	291
COR_L*	844	106	-	-	-	-	950	0.11 (0.32)	286
COR_B*	434	516	-	-	-	-	950	0.54 (0.50)	93

- Not relevant

1. Fixed effects

Week off test, sex, performance test system and breed affected conformation scores in diminishing order, but overall explained relatively little variation (generally R^2<3-5%). The exceptions were for front pasterns and correct legs (binary), where 8-10% of the variation in scores was associated with scoring week. Sex+breed explained a further 10% of the variation in front pasterns. While significant regression coefficients for some conformation traits on performance traits were obtained, variation in weight, lifetime average daily gain, eye muscle depth or average fat depth generally explained relatively little of the variation in conformation scores (additional R^2<1-2%).

Significant ($P<0.05$) regression coefficients for scores on final weight or average daily gain were positive for front pasterns (weight: 0.005±0.002), front view (weight: 0.002±0.001) and hocks (ADG: 0.0008±0.0004) in finishers. For animals performance tested in electronic feeders, coefficients were positive for standing out at the back (ADG: 0.0014±0.0006) and injuries (ADG: 0.010±0.005), but negative for back shape (ADG: -0.006±0.002). Significant regression coefficients on eye muscle depth were 0.008±0.003 (finishers) for back pasterns and 0.023±0.009 (feeders) for standing out at the front. Coefficients for the regression of conformation traits on ultrasonic fat depth were 0.109±0.056 for hocks and –0.429±0.181 for injuries, for animals performance tested in electronic feeders.

In this data, the overall implications of regression coefficients for conformation scores must be considered within performance test procedure, which differ in age and target weight at end of test. Moreover, linear regressions are only approximate for categorical or binary traits and are small in magnitude. Nevertheless, results suggest that faster growing, leaner animals with larger eye muscle depth are slightly more likely to appear as O-shaped or standing outwards and to have superficial injuries.

2. Parameter estimates

Estimates of heritabilities and corresponding variances are presented in Table 3. Heritability estimates for leg conformation traits ranged from negligible (hocks) to high (front pasterns). Estimates for body conformation traits were negligible (shape) to low (front and rear view traits). The binary traits (injured, correct legs, correct body shape) were highly to lowly heritable. Corresponding estimates of heritability from linear methods, converted to the underlying scale, were 0.32, 0.19 and 0.14 respectively, supporting the magnitude of estimates for these traits. Estimates of heritabilities for the average of combined leg scores were high (0.35±0.09) for front legs, low (0.10±0.06) for back legs, and moderate (0.30±0.08) overall. For average combined front leg scores, a model fitting litter effects concurrently with additive genetic effects was significantly better than a model fitting the latter effect alone. Estimates of heritability and common litter effects in this case were 0.08±0.08 and 0.15±0.05, respectively, suggesting a strong early environmental component (ie litter effects) on the appearance of front leg conformation. The much lower heritability estimate under this model suggests that direct response to selection on front leg score would be limited.

Phenotypic variances for all conformation traits were low, which is characteristic of categorical traits with few scoring categories. Variances were further reduced for average combined score traits. Phenotypic variances for the binary traits (injured, correct legs, correct body shape) are inflated, because residual variances for binary traits are fixed to 1.0 (Gilmour *et al*., 1999).

Larochelle (1999), in a review of conformation related literature, reported average heritabilities of 0.40 for front pasterns, 0.19 for back pasterns, 0.18 for front legs and 0.12 for back hocks. Average heritabilities for leg weakness traits reported by Clutter *et al* (1998), who reviewed different conformation studies, ranged from 0.16 to 0.30. Grindflek and Sehested (1996) reported very similar estimates of heritability for front pasterns, hock and back pastern scores to those obtained here. While direct comparisons between studies are hindered because of different scoring systems, similar estimates of heritabilities are generally indicative of the low to moderate heritability of leg conformation traits and moderate to high heritability of feet conformation traits in pigs. The binary traits, injured and correct legs, were moderately to highly heritable.

Table 3 Estimates of heritabilities (h^2 ± standard error), additive genetic (σ^2_a), between sire variances (σ^2_{sire}) and phenotypic (σ^2_P) variances for conformation traits

Trait	$h^2 \pm$ se	σ^2_a	σ^2_{sire}	σ^2_P
Front wrists	0.16 ± 0.07	0.05	-	0.34
Front pasterns	0.42 ± 0.09	0.16	-	0.37
Combined front average	0.35 ± 0.09	0.08	-	0.23
Back hocks	0.00 ± -	0.00	-	0.35
Back pasterns	0.27 ± 0.08	0.07	-	0.26
Combined back average	0.10 ± 0.06	0.02	-	0.16
Combined legs average	0.30 ± 0.08	0.04	-	0.12
Front view	0.12 ± 0.08	0.01	-	0.04
Standing out -front	0.12 ± 0.05	0.03	-	0.23
Rear view	0.12 ± 0.07	0.01	-	0.11
Standing out - rear	0.06 ± 0.05	0.01	-	0.10
Back shape	0.01 ± 0.04	0.01	-	0.02
Injured	0.42 ± 0.20	-	0.12	1.12
Correct legs	0.30 ± 0.19	-	0.08	1.08
Correct body	0.14 ± 0.10	-	0.04	1.04

- not fit; *estimates are on the underlying scale, residual variance fixed to 1.0

3. Did scored conformation traits have any association with later culling decisions?

Of the 950 animals whose conformation scores were used in analyses, 526 (55%) have already been culled, with date of and reason for removal known. Thus, it is possible to make a preliminary investigation of whether specific conformation defects were associated with the reason(s) for culling. All culling was performed by staff at QAF operating independently of the scorer for conformation traits.

“Feet and legs” was overall the main reason for culling (25.7% of all animals culled). However, for this study normal culling for poor conformation occurred after selection, whereas much of the culling for conformation would normally be conducted before selection. The number of animals removed for feet and leg problems per four-week period is shown in Table 4. In the first month, many of the removals were animals reported as previously injured. In the second month, gilts and boars were transported, and the bulk of culling for feet and leg issues occurred at this stage – prior to mating. During the first two months, several animals (12) previously scored with correct legs were culled for feet and leg related problems, and only four of these were noted as injured at selection. This may indicate a level of discrepancy between scores at selection and the feet or leg conformation perceived by other staff, or post-selection issues (eg. injury during transport). By the third month and later, animals identified at selection to have problems in this area dominated all removals for feet and leg issues. However, it should be noted that few animals overall had completely correct conformation for all limbs.

It is important to note that 83.7% of all animals removed for feet and legs had been culled in the first three months after selection. This makes it difficult to quantify whether animals with incorrect conformation would have survived the rigours of production in the sow herd. The bulk of animals culled for feet and legs had not been exposed to a breeding situation (males or females) or housing and conditions typically encountered by breeding sows (females only). Reasons for removal at QAF showed very few animals culled with gross locomotory problems (eg. inability to get up, stand and walk).

Table 4 Overview of culling for feet and leg problems after selection

Weeks	No. culled	scored with		
		all legs correct	incorrect leg(s)	an injury
1-4	15	3	12	8
5-8	84	9	75	11
9-12	14	1	13	1
13-16	4	0	4	0
17-20	3	0	3	0
21-24	1	0	1	0
25-36	14	2	12	0
Total	135	15	120	20

With respect to individual leg traits, a breakdown of the number of animals recorded with incorrect conformation, and subsequently culled, is shown in Table 5. Overall, the proportions of animals scored with incorrect conformation for wrists, front pasterns, hocks or back pasterns, and which were subsequently culled, were 23, 27, 25 and 30% respectively. Thus, greater emphasis on removing animals with poorer conformation for front and rear pasterns is realised in practice, and much of this occurs before animals are mated, as noted above. Of note, the majority of animals culled with incorrect conformation for front pasterns had 'weak' pastern scores.

Table 5 The number of animals culled for feet and leg problems with incorrect conformation for leg traits, by weeks after selection.

Weeks	No. culled	with incorrect conformation for			
		Wrists	Front pasterns	Hocks	Back pasterns
1-4	15	7	5	2	2
5-8	84	27	49	27	25
9-12	14	5	4	5	4
13-16	4	1	2	0	1
17-20	3	3	0	1	1
21-24	1	1	0	0	0
25-36	14	6	6	8	3
Total (%)	135	50 (0.37)	66 (0.49)	43 (0.32)	36 (0.27)

4. **Which leg conformation traits are important?**

This particular study does not enable us to directly assess which conformation traits have a more significant impact on sow longevity. However, other studies have demonstrated that buck-kneed forelegs, swaying hindquarters, standing under and upright pasterns on fore- or hind-legs are associated with reduced sow longevity due to locomotory problems. In contrast, sows with weak front pasterns have better longevity, and this is thought to result from a better gait (eg. Grindflek and Sehested, 1996; Jorgensen, 1996). Thus, not all deviations from correct or normal conformation will have detrimental affects for sow longevity.

Take home messages

1. Not all conformation traits are heritable. Thus, culling for some conformation traits during or after the selection process will reduce response in the defined breeding objective, without any expectation of improved conformation in the future herd.

2. Animals that are faster growing and leaner tend to deviate from the correct conformation for front legs. Those with larger eye muscle depth are more likely to deviate from the correct back leg scores and rear view. These results would suggest that independent culling for conformation traits would differentially remove animals with superior performance for production traits.

3. Front and back pastern scores are more heritable than scores for wrists or hocks. The averages of combined scores (combined front, combined legs) are moderately heritable, but less variable. There is a suggestion that litter effects are a significant source of variation for observed front leg conformation.

4. Discrepancies will probably exist between individual staff when examining the same animals for conformation traits.

5. It is difficult to establish with this data whether animals with less correct conformation would have reduced longevity in the breeding herd. Some studies show favourable outcomes for deviations away from correct conformation. For example, a description of ‘weak’ for pasterns is not necessarily very informative.

6. Further investigation is necessary to determine whether there are economic benefits to directly improving heritable conformation traits through selection, and whether there are genetic associations between these conformation traits and economically important performance traits.

7. Identification of the important traits for functionality, implementation of linear scoring systems, and appropriate selection emphasis is the preferred option.

Acknowledgments

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