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GENETIC VARIATION IN GROWTH PATTERNS IS ASSOCIATED WITH SOW LIFETIME PERFORMANCE

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SUMMARY

Longitudinal data for weight and fat from up to 19 recording events were used in random regression (RR) analyses to generate estimates of additive genetic and permanent environmental effects for sow development attributes up to parity 5. Sows (N=3324) were then ranked in quartiles using solutions from the RR for additive genetic effects which separately describe intercept and slope, generating 16 combinations (intercept×slope) for development trajectories within trait. Lifetime productivity of sows was compared between these groups. Genetic variation in development trajectories was evident, but similar phenotypes can arise from different trajectories. Differences in lifetime productivity, measured as the total number of piglets born (LTB) or litters produced (LPL) prior to culling, was significantly associated with genetic differences in development patterns. While sows survived and reproduced over a wide range of body weights and adiposity levels, generally heavier and fatter sows were more likely to enter the breeding herd successfully. However, sows with low rank for intercept combined with high rank for slope, putatively representing a "later" development pattern that should increase competition for limited resources in the breeding sow, had significantly ($P<0.0001$) reduced LPL and LTB in particular. This outcome suggests that associations between traits like body weight and fatness with sow lifetime performance are not independent of the timing in body development relative to the physiological demands of reproduction.

INTRODUCTION

Selection to increase lean growth has consequences for ongoing development characteristics of breeding sows. Modern sows are larger and leaner than their historical counterparts (Hermesch *et al.* 2010), produce piglets with higher growth potential, and may also have increased litter sizes. Therefore, the demands on sow energy reserves during gestation and lactation have increased while their expendable resources, in the form of body fat, have diminished. As an apparent consequence of these altered sow attributes, sow longevity has decreased. However, associations between production related traits and sow longevity remain unclear. In a previous study, it was demonstrated that higher growth rates were advantageous for sow longevity in early parities (eg parity 1 or 2) but heavier weights become increasingly detrimental for survival to later parities (Bunter *et al.* 2010). In contrast, sows able to accumulate fat earlier in life (eg pre-breeding and the first farrowing) were consistently more likely to stay in the herd and therefore produce more litters (Bunter *et al.* 2010). Therefore, the associations between weight and longevity appear to change over time, whereas those with fat do not, and this outcome might be related to different patterns of development. In this study, we used solutions from a random regression analysis to assess whether genetic differences in growth and fat deposition patterns to 30 months of age were associated with differences in sow lifetime performance, as measured by their lifetime reproductive output.

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MATERIAL AND METHODS

Longitudinal data from up to 19 recording events per sow were used in random regression analyses of sow development attributes for weight and fat depth up to parity 5. Recording events occurred at 20, 21, 26 and 29 weeks of age, followed by records at mating, day 110 (D110) of gestation and weaning for parities 1 through to 5. Not all sows had all measurements, with missing records mostly following early culling. Details of the development of the random regression analyses, performed using ASREML(Gilmour *et al.* 2006), are reported only briefly here. The fixed effect models for the weight and fat depth traits accounted for sow line (2 levels), contemporary group at selection (CGP: year-month) and development phase, along with pregnancy status and regressions on age at recording nested within production phase. Three development phases were defined to improve the fit of systematic models for weight: phases were defined as development to 29 weeks, from 29 weeks to weaning in parity 1, and subsequently records from later parities. These phases encompass different development rates, along with housing and management (including feeding) strategies. The latter two phases were combined for analyses of fat depth.

Residual variances were estimated separately for each recording event. For random effects pertinent to the sow, Legendre polynomials for the regression of weight (fat) on age were fitted to the fourth order, to obtain sets of random regression coefficients for both additive genetic (a_i={a_0,…,a_4}) and permanent environmental effects (p_i={ p_0,…,p_4}) for each (*i*th) sow. Using appropriate scale, solutions from a_i and p*i* were then used to generate predicted weight and fat depth ($= a_0 + \sum_{j=1}^{4} a_j \times age^j + p_0 + \sum_{j=1}^{4} p_j \times age^j$) at 30 months of age, which coincides approximately with the age at mating for a fifth parity. Sows were also ranked into ascending quartiles separately based on a_0 (the intercept: iQ1-iQ4) and $\sum_{j=1}^{4} a_j \times age^j$ (hereafter called the slope, for which the summation represents the net effect: sQ1-sQ4) to investigate associations between genetic contributions to sow development and their lifetime productivity traits.

Lifetime productivity for each sow was defined as the total number of piglets born (LTB) and the lifetime number of litters produced (LPL) from parities 1 through 5. Sows selected but not farrowed received a record of zero for both traits. Complete inventories were available for project females. Therefore, age at all recording events was known. Systematic effects for LTB and LPL included CGP and sow line, as above. Quartile rank (intercept×slope) was also fitted in the model to obtain least squares means for each group. The significance of differences between these groups was tested using a Bonferroni correction for multiple comparisons.

RESULTS AND DISCUSSION

Observed patterns for weight and fat depth for this population are shown in Figure 1, along with the predicted mean values from the fixed effects model for non-pregnant sows. On average, sows continued to grow up to parity 5. In contrast, the relatively high fat depth accumulated prior to the first farrowing was not followed by substantial accretion thereafter, other than during the state of pregnancy. Fat deposition during pregnancy has been reported previously (Young *et al.* 2005), and is an important energy source which is therefore typically lost (used) during lactation (Figure 1). Although sow development patterns are rarely published, similar patterns for both weight and fatness were reported by O'Connell *et al.* (2007) for sows representing different parities recorded throughout a single gestation.

No other studies have investigated genetic contributions to sow growth and development patterns over their lifetime. Generally, there was considerable variation amongst sows in their predicted development pattern which, in combination with patterns for correlations between permanent environmental effects, reflected relatively low genetic correlations between early (week 20) and later weights in particular (not presented here). Heritability estimates declined with age to moderate levels (~0.2-0.3) for both traits; corresponding estimates of additive genetic variation increased for weight and declined for fat (results not shown). Predicted means (predicted range) for weight and fat at 30 months were 272 kg (196-367 kg) and 16.2 mm (9.50-25.7 mm) (for N=3324). Observed means (observed range) at mating in parity 5 (N~450) were 263 kg (206-337 kg) and 16.1 mm (8-26 mm). The same phenotypes could result under different growth patterns and consequently phenotypes overlapped between groups based on quartile ranks.

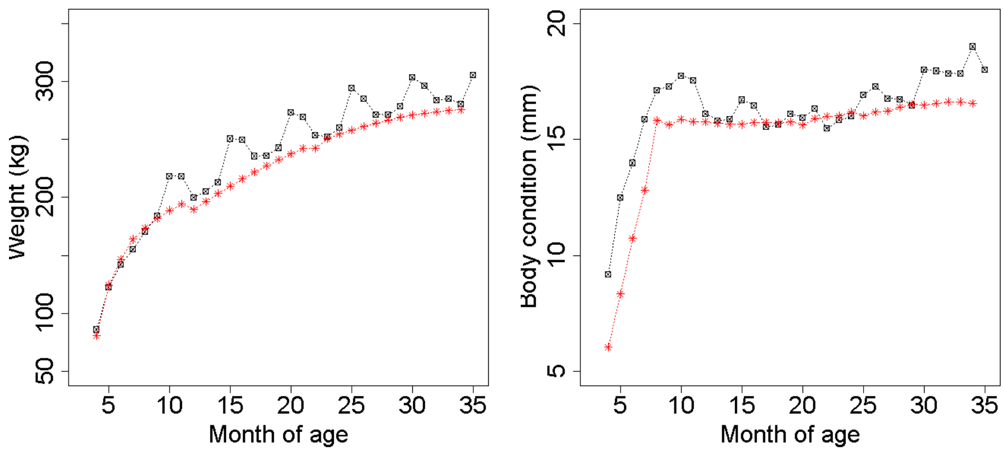

Figure 1. Raw means (squares) showing the pattern of development as physiological state and age change, along with the predicted (stars) weight and fat depths for status=non pregnant from the fixed effect model.

The distribution of sows across within trait combinations of quartile classes (not presented) showed that the associations between intercept and slope were positive for weight but negative for fat. Sows ranked in the middle quartiles (sQ2&sQ3) for weight and fat depth had fewer records due to earlier culling; consequently their random regression coefficients for slope were also regressed towards mean values. Therefore, only sows present in sQ1 and sQ4 were compared for lifetime performance (Table 1).

Both heavier and fatter sows were more likely to enter the herd and farrow at least once (compare N, Table 1), consistent with the influence of adequate gilt development on the probability of reproductive success and the positive genetic correlations between weight and fat depth (Bunter *et al.* 2010). However, for LTB and LPL the effect of intercept×slope was generally significant (P<0.05, results not shown) and, therefore, the effect of slope differed according to intercept, representing early weights. The lifetime productivity of sows which ranked lower for intercept (iQ1&iQ2) was significantly reduced when the rank for slope was high (sQ4), suggesting that sows with increased genetic potential for "late" increases in weight and fat, relative to their lower expression at selection, were disadvantaged with respect to maintaining reproductive outcomes (eg LTB or LPL). For sows ranked in iQ3, there was no significant effect of slope, while for sows ranked in iQ4, the highest lifetime performance was conversely observed in sQ4. Sows ranked in iQ4/sQ4 (slope/intercept) were the fattest, on average, and the ability to store fat confers a reproductive advantage in many species (Schneider 2004). Since the proportions of sows represented in different classes are clearly unequal and phenotypes overlap across classes, such associations may be difficult to observe in raw data.

Table 1. Mean predicted weight (kg) and fat (mm) at 30 months for sows (N=3324) ranked on their genetic merit for intercept (iQ1-iQ4) and slope (sQ1-sQ4) attributes, along with LSM for lifetime total born (LTB) and litters per lifetime (LPL)

		Ranked within weight		Ranked within fat	
	Rank	sQ1	sQ4	sQ1	sQ4
N (N in P1)	iQ1	339 (294)	92 (58)	28 (27)	466 (278)
	iQ2	203 (153)	159 (86)	69 (59)	232 (114)
	iQ3	170 (112)	208 (141)	214 (126)	93 (58)
	iQ4	119 (87)	372 (334)	520 (350)	40 (39)
Predicted weight (fat)	iQ1	240 (14.7)	256 (15.7)	248 (13.1)	262 (14.2)
	iQ2	260 (15.7)	270 (16.1)	259 (14.7)	273 (16.1)
	iQ3	273 (16.1)	281 (16.7)	270 (16.2)	279 (17.4)
	iQ4	289 (17.0)	306 (17.9)	282 (18.6)	297 (19.9)
LSM LTB	iQ1	30.1	20.3****	34.7	17.3****
	iQ2	26.5	18.4****	31.1	15.1****
	iQ3	22.8	23.4	18.3	21.5
	iQ4	25.7	32.4***	21.9	40.0***
LSM LPL	iQ1	2.65	2.09**	3.21	1.52**
	iQ2	2.28	1.68***	2.81	1.34***
	iQ3	1.96	2.07	1.62	1.92
	iQ4	2.23	2.87***	1.93	3.65***

Significance test: sQ1 vs sQ4 within weight or fat; ****p<0.0001; ***p<0.001; **p<0.01; p<0.05

CONCLUSIONS

Mechanisms that control energy balance in animals are generally linked to reproductive success (Schneider 2004). However, results from this study suggest that patterns of development are also associated with the lifetime performance of sows. Differences in these patterns are currently not accommodated by selection strategies or management options (eg nutrition). Further examination of variation in development patterns and their role for sow longevity may be warranted.

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