Objective evaluation of female feet and leg joint conformation at time of selection and post first parity in swine[1]

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ABSTRACT: Feet and legs of replacement females were objectively evaluated at selection, i.e., approximately 150 d of age ($n = 319$) and post first parity, i.e., any time after weaning of first litter and before second parturition ($n = 277$) to 1) compare feet and leg joint angle ranges between selection and post first parity; 2) identify feet and leg joint angle differences between selection and first 3 wk of second gestation; 3) identify feet and leg joint angle differences between farms and gestation days during second gestation; and 4) obtain genetic variance components for conformation angles for the two time points measured. Angles for carpal joint (knee), metacarpophalangeal joint (front pastern), metatarsophalangeal joint (rear pastern), tarsal joint (hock), and rear stance were measured using image analysis software. Between selection and post first parity, significant differences were observed for all joints measured ($P < 0.05$). Knee, front and rear pastern angles were less (more flexion), and hock angles were greater (less flexion) as age progressed ($P < 0.05$), while the rear stance pattern was less (feet further under center) at selection than post first parity (only including measures during first 3 wk of second gestation). Only using post first parity leg conformation information, farm was a significant source of variation for front and rear pasterns and rear stance angle measurements ($P < 0.05$). Knee angle was less (more flexion; $P < 0.05$) as gestation age progressed. Heritability estimates were low to moderate (0.04–0.35) for all traits measured across time points. Genetic correlations between the same joints at different time points were high (>0.8) between the front leg joints and low (<0.2) between the rear leg joints. High genetic correlations between time points indicate that the trait can be considered the same at either time point, and low genetic correlations indicate that the trait at different time points should be considered as two separate traits. Minimal change in the front leg suggests conformation traits that remain between selection and post first parity, while larger changes in rear leg indicate that rear leg conformation traits should be evaluated at multiple time periods.

Key words: digital imagery, feet and leg conformation, gilts, joint measurements

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INTRODUCTION

Selection of replacement gilts occur at a single point in time in an animal's life. This point in time is typically used to evaluate traits used as predictors

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or indicators of the animal's ability to live a long and productive life. Feet and leg conformation frequently comprises a significant portion of this selection process. However, when producers evaluate their replacement gilts for proper feet and leg conformation, they are still in the rapid growth phase of their life (Robison, 1976). Only one study, Fernàndez de Sevilla et al. (2009), has reported on conformation changes between time of selection and any time point after. This indicates a gap in knowledge on whether conformation at the time of selection is any indication for conformation across later time periods. Feet and leg problems are commonly listed as one of the leading causes for early removal of females from commercial swine breeding herds (D'Allaire et al., 1987; Boyle et al., 1998; Mote et al., 2009), indicating lost opportunity from animals that either were not selected correctly or had drastic feet and leg conformation changes that occurred post selection. Several feet and leg conformation traits, such as metacarpophalangeal joint (front pastern), metatarsophalangeal joint (rear pastern), carpal joint (knees), and tarsal joint (hock) position, are associated with improved longevity and survivability in sows (Stalder et al., 2004). Identifying the "ideal" angles for these joints, that when selected upon early in life and are maintained, could help make more informed feet and leg selection decisions. Likewise, understanding any key feet and leg conformation changes occurring in these joints across the animal's life could help producers make better decisions when selecting breeding herd replacement females. To this purpose, the first objective of this study was to compare feet and leg angle ranges from gilts at selection and post first parity. A second objective was to identify feet and leg angle differences in gilts at selection and during the first 3 wk of their second gestation. The third objective was to use the feet and leg measures collected during second gestation to identify differences among farms and gestation days to identify potential environmental and gestational effects. Finally, the last objective of this study was to obtain genetic variance and covariance components for objective feet and leg conformation traits from replacement gilts collected at selection and post first parity to better understand the genetic relationships among these traits.

MATERIALS AND METHODS

Care and Use of Animals

This study was conducted in accordance with the Guide for the Care and Use of Agricultural Animals in Research and Teaching as issued by the American Federation of Animal Science Societies (FASS, 2010). Videos were collected during routine farm evaluation and training and no excess measures or involvement between the animal and study were required beyond normal farm procedures.

Feet and leg conformation traits from 319 commercial crossbred females with a three-generation pedigree and raised on a single gilt development unit, under the same management and fed the same development ration were evaluated at 19 to 25 wk of age (133 to 175 d), referred to hereafter as selection. Gilts were selected for inclusion in the study based on the following criteria: 1) mobility, 2) no severe injuries, 3) exclusion of females too small for selection. From the gilt development unit, the animals were separated and transferred approximately equally across three breed-to-wean sow units, where they remained for the duration of this study and fed the same ration, but under three different management conditions. Carpal joint (knee), metacarpophalangeal joint (front pastern), metatarsophalangeal joint (rear pastern), tarsal joint (hock), and rear stance were measured at selection, i.e., approximately 150 d of age ($n = 319$). Measurements were again recorded post first parity, i.e., any time after first weaning and before second parturition ($n = 277$), unless the animal was culled, died, or euthanized prior to second gestation. Those 277 females either recently had litters weaned or had been mated for their second gestation. The difference (42 females) resulted from females that were removed from the study with eight of the females being removed because they had at least one leg deficiency (bad legs, downer, lame). According to the sow culling records, 14 animals were removed from the breeding herd for reproductive problems, four females each were removed due to sudden death and illness/injury and the remaining 12 for unknown reasons. There were small biological differences in the average joint values at selection of all animals culled and those that remained for evaluation post first parity when compared to the overall average (Table 1), indicating that joint conformation was likely not a reason for removal. Due to the commercial nature of this study and logistics, it was not feasible to collect video evaluation during post first parity at the same time point for every animal that remained in the breeding herd post first parity. Therefore, animals were evaluated at the time point when all remaining animals had completed their first litter weaning event (post first parity). Animals during this second evaluation period were either recently weaned (considered gestation age zero) or in their second gestation, resulting in a range in

Table 1. Joint angles (degrees) of breeding herd female feet and leg conformation traits[1] (mean and SD) at age of selection for animals remaining post first parity, animals removed prior to post first parity and all animals measured at selection

	Remaining post first parity[2]		Removed prior to first parity[3]		All animals at selection[4]	
	Mean	SD	Mean	SD	Mean	SD
Knee	164.6	5.5	165.6	5.5	164.7	5.5
Front pastern	54.7	5.3	54.2	5.3	54.7	5.3
Rear pastern	57.5	6.1	58.2	5.0	57.6	6.4
Hock	140.8	6.4	140.6	6.7	140.8	5.9
Rear stance	91.9	6.5	91.9	5.7	91.9	6.4

[1] Evaluated as per Stock et al. (2017) using an objective method based on digital images

[2] Females (n = 277) remaining for evaluation post first parity.

[3] Females (n = 42) removed prior to first parity.

[4] Females (n = 319) measured at selection.

gestation weeks post first parity (0 to 12.4 wk of second gestation).

Image Collection

Gilt feet and leg image collection and image processing followed a similar procedure to those described by Stock et al. (2017). A still-frame camera, a Bell + Howell Take 1 HD Digital Camcorder (Bell and Howell, US, Wheeling, IL) on HD 1280 × 720P settings was used to capture digital video images. Videos were reviewed to be sure the animal was in the correct standing position and then individual digital image frames were extracted from the videos using AVCutty (AVCutty v3.5, Andreas von Damaros, Krefeld, Germany, www.avcutty.de). Multiple frames were captured from each video. On average, 6.4 profile and 2.1 rear stance images per animal were used for measuring joint angles for the different feet and leg conformation traits studied.

Trait Evaluation Procedure

Trait evaluation procedures have been previously described by Stock et al. (2017). The joints examined included the knee, front and rear pasterns, and the hock at approximately 150 d of age (±12.6 d) and post first parity (second gestation average 3.9 wk ± 2.5 wk; range 0 to 12.4 wk), if the animal had not been previously removed from the breeding herd. The rear stance position from each female was also objectively evaluated during these time periods.

Data Analysis

Each animal was considered an experimental unit. Each joint angle measurement was analyzed using mixed model methods (PROC MIXED of SAS v9.3, SAS Inst. Inc., Cary, NC). Three separate models were developed for analysis. The first model was used to investigate differences between the two measurements within the same animal. All animals were included for this analysis. A repeated measures model was implemented to analyze data comparing joint and leg traits from gilts evaluated at selection and post first parity, including parity (i.e., zero and one) as a fixed effect and animal included as a repeated measure. Due to the gilts being raised in the gilt development unit together and being transferred across three farms, herd is confounded with parity in the repeated measures model; therefore, it was excluded from the model. Due to evaluation range of gestation days mentioned previously, this model could be biased due to the added weight of gestation in a portion of these animals, which was not able to be accounted for. To account for any additional weight due to gestation, the second model developed used a subpopulation of those evaluated in the first model, and only included the records (selection and post first parity) for those animals evaluated that were measured post first parity during gestation weeks 0 to 3 (n = 126). A repeated measures model was used to analyze the data comparing feet and leg conformation traits measured in the subpopulation with parity (i.e., zero or one) included as a fixed effect and animal as a repeated measure. Farm was excluded from this model for the same reasons previously stated. Lastly, the final model was developed to look at gestation week and farm differences, specifically post first parity. All animals remaining (not culled or removed) at post first parity collection were included in this analysis. The model for determining the gestation age effects on feet and leg conformation angles during the females' second gestation included farm as a fixed effect and gestation age as a continuous linear covariate. The quadratic term for gestation age was originally fit in all models to test for significance but was only included in the final rear stance model due to its significance. Animal was included as a random effect. Statistical differences were reported when individual model main effects were a significant source of variation ($P \leq 0.05$). Furthermore, when individual model main effects were a significant source of variation, main effect levels were separated using the PDIFF option (SAS v 9.3), which returns the P values for least squares means differences between different levels within each level of fixed class effects. Results for fixed effects are reported as least squares means ± SE (LS means ± SE). Results for covariates are reported as regression coefficients ± SE.

Variance Component Estimation

Animal genetic effects were estimated using the animals' full pedigree back to the grand-parent generation. Variance components for each joint were estimated using single-trait (heritability) and two-trait (heritability and genetic correlation) animal models with AIREMLF90 (Misztal et al., 2014). Bivariate models were evaluated across traits within each time frame, and within trait across time frames. Different traits were not evaluated across time frames. For single-trait evaluation, age (in weeks) and measurement date were included as fixed effects in the animal model for time at selection and farm and gestation week for post first parity similar to the model previously described. For multitrait evaluation within traits, farm was included as an effect in the animal model. Since REML was used to estimate the variance components, they should be free of any selection bias (Rothschild and Henderson, 1979). Heritability estimates for each joint at the time of selection (i.e. parity 0) and post first parity (i.e. parity 1) were calculated using the additive genetic variance divided by total variance. Heritability estimates were calculated from both the single-trait animal model and the multi-trait animal model to compare the two estimates. Standard errors for the heritability estimates were calculated using the method described in Tsuruta (2008). Genetic correlation SE were estimated as described by Falconer and Mackay (1996).

RESULTS

Comparison of Feet and Leg Traits Between Selection and Post First Parity

Feet and leg joint angle by parity LS means is presented in Table 2 as the entire population and as a subpopulation of animals during post first parity evaluation between 0 and 3 wk of gestation. Full population analysis found replacement females had greater knee, front and rear pastern angles (less flexion) at selection when compared to post first parity ($P < 0.05$), with differences of 6.4, 2.6, and 7.3 degrees, respectively. Hock angles were less (more flexion) by 6.1 degrees ($P < 0.05$) at selection in the replacement females when compared to the same traits evaluated post first parity. Rear stance of the replacement females was less (feet further under center) by 5.3 degrees ($P < 0.05$) when measured post first parity compared to the same traits evaluated at selection. One-hundred-twenty-six animals, of the original 319 replacement females were evaluated between gestation weeks 0 to 3 of their second gestation. Subpopulation analysis found replacement females had greater knee, front and rear pastern angles (less

Table 2. Joint angles (degrees) of breeding herd female feet leg conformation traits[1] (least squares means ± SE) at age of selection and post first parity

	Entire population[2]				Subpopulation[3]			
	Selection		Post first parity		Selection		Post first parity	
	LS Means	SE	LS Means	SE	LS Means	SE	LS Means	SE
Knee	164.7^a	0.3	158.3^b	0.3	164.7^a	0.5	158.6^b	0.5
Front pastern	54.7^a	0.3	52.1^b	0.4	54.8^a	0.6	51.6^b	0.6
Rear pastern	57.6^a	0.3	50.3^b	0.3	57.5^a	0.5	50.1^b	0.5
Hock	140.8^a	0.3	146.9^b	0.3	141.1^a	0.5	146.4^b	0.5
Rear stance	91.9^a	0.3	86.6^b	0.4	91.4^a	0.6	86.2^b	0.6

[1] Evaluated as per Stock et al. (2017) using an objective method based on digital images.

[2] Females evaluated approximately at 150 d of age at the point of selection ($n = 319$) and 0 to 12 wk of second gestation post first parity ($n = 277$).

[3] Females evaluated approximately at 150 d of age at the point of selection ($n = 319$) and subpopulation of second gestation post first parity evaluated between 0 and 3 wk ($n = 126$).

[a,b] Within row and population, significant differences between predictor variables; $P < 0.05$.

flexion) at selection when compared to the same measurement made during their second gestation period ($P < 0.05$), with differences of 6.1, 3.2, and 7.4 degrees, respectively. Hock angles were greater (less flexion) by 5.0 degrees ($P < 0.05$) as age progressed from selection into the second gestational period. Rear stance was less (legs turned in) by 5.2 degrees ($P < 0.05$) at second gestation period when compared to hock measures evaluated at time of selection.

Effects of Farm and Gestation Age at Second Gestation

There were significant ($P < 0.05$) front and rear pastern joint angle differences as well as rear leg stance position differences between farms (Table 3). However, the differences were biologically small (2.6 to 3.5 degrees) except for rear stance position of females in farm C that were 6 degrees less (feet further under center) than both farms A and B ($P < 0.05$). As second gestation age progressed knee angle and rear stance angle position was less (more flexion; $P < 0.05$) although a greater angle (feet farther under center) in rear stance position was observed when second gestation age was included as a quadratic covariate ($P < 0.05$; Table 3).

Heritability, Phenotypic, and Genetic Correlations

Heritability (single-trait), phenotypic, and genetic correlation estimates for the joint angles measured at time of selection and post first parity are presented in Tables 4 and 5, respectively. Single-trait animal model heritability estimates were low to moderate for all traits measured and ranged from 0.04 to 0.35. Single-trait animal model heritability estimates were lower numerically when measured at selection when compared to estimates for the same traits collected post first parity in the knee, front pastern, and the hock by 0.05, 0.10, and 0.11, respectively, due to increased residual variation at selection. Single-trait animal model heritability estimates were greater numerically at selection when compared to estimates for the same traits collected post first parity in the rear pastern and rear stance position, with a difference of 0.12 and 0.19, respectively, due to a reduction in genetic variation. Although there were numeric differences between heritability estimates across time points, all were within SE of their alternate time point. Phenotypic correlation estimates between the joints and for joint angle difference at selection and post first parity were all small. Genetic correlation estimates were small and most SE were greater than the estimates. Heritability (two-trait) and genetic correlation estimates for the joint angles measured at time of selection and post first parity (range 0.19 to 0.36 heritability; −0.06 to 0.99 genetic correlation) are presented in Table 6. Single and bivariate models were run to evaluate similarities between the models. Heritability estimates between the single-trait and two-trait animal models were similar and within SE of one another, except in the rear stance measure, where the animal model did not converge. Genetic correlations for the front leg traits (knee and front pastern) between the two time points of selection and post first parity were high (0.91 and 0.99, respectively). Rear leg trait (hock and rear pastern) genetic correlations were low (−0.06 and

Table 3. Joint angles for breeding herd female feet leg conformation trait[1] (least squares means ± SE) from 277 post first parity sows housed in three different farms from 0 to 12.4 wk of gestation

	Knee		Front pastern		Rear pastern		Hock		Rear stance	
Variable	LS Means	SE	LS Means	SE	LS Means	SE	LS Means	SE	LS Means	SE
Farm[2]										
A	158.8[a]	0.6	52.6[a]	0.7	51.4[a]	0.5	147.3[a]	0.5	88.5[a]	0.7
B	158.4[a]	0.6	53.5[a]	0.7	51.3[a]	0.5	146.8[a]	0.5	88.4[a]	0.7
C	157.5[a]	0.6	50.0[b]	0.8	47.6[b]	0.6	146.5[a]	0.5	82.4[b]	0.7
Gestation age[3]										
Linear	−0.29 ± 0.01*		−0.01 ± 0.17		−0.06 ± 0.13		0.19 ± 0.12		−1.25 ± 0.17*	
Quadratic	NS		NS		NS		NS		0.14 ± 0.05*	

[1] Evaluated as per Stock et al. (2017) using an objective method based on digital images.

[2] Females originated from a single gilt development unit and were distributed across three farms, (farm A—$n = 97$, farm B—$n = 98$, and farm C—$n = 82$) after selection at approximately 150 d of age.

[3] Results for continuous linear and quadratic covariates are presented as the regression coefficient ± SE.

[a,b] Within columns, significant differences between predictor variables ($P < 0.05$).

*$P<0.05$.

NS = not significant.

Table 4. Linear model heritability estimates (±SE; diagonal; single-trait), genetic (±SE; above diagonal; multitrait), and phenotypic (below diagonal) correlation estimates for objectively measured[1] feet and leg angles in 319 gilts at selection

Traits	Knee	Front pastern	Rear pastern	Hock	Rear stance
Knee	0.21 ± 0.09	−0.04 ± 0.37	0.35 ± 0.06	0.03 ± 0.36	NA[2]
Front pastern	0.00 ± 0.06	0.23 ± 0.10	0.36 ± 0.27	0.28 ± 0.31	NA
Rear pastern	0.08 ± 0.06	0.30 ± 0.05	0.35 ± 0.10	0.05 ± 0.09	NA
Hock	0.16 ± 0.06	0.14 ± 0.06	0.03 ± 0.06	0.19 ± 0.09	NA
Rear stance	−0.04 ± 0.06	0.07 ± 0.06	0.15 ± 0.06	−0.12 ± 0.06	0.23 ± 0.17

[1] Evaluated as per Stock et al. (2017) using an objective method based on digital images.

[2] NA = not applicable; model did not converge.

Table 5. Linear model heritability estimates (±SE; diagonal; single-trait), genetic (±SE; above diagonal; multitrait), and phenotypic (below diagonal) correlation estimates for objectively measured[1] feet and leg angles in 277 sows post first parity

Traits	Knee	Front pastern	Rear pastern	Hock	Rear stance
Knee	0.26 ± 0.11	−0.47 ± 0.37	−0.33 ± 0.38	−0.19 ± 0.31	NA[2]
Front pastern	0.21 ± 0.06	0.33 ± 0.10	0.42 ± 0.27	−0.21 ± 0.27	NA
Rear pastern	0.02 ± 0.06	0.16 ± 0.06	0.23 ± 0.10	−0.12 ± 0.32	NA
Hock	0.03 ± 0.06	0.15 ± 0.06	0.10 ± 0.06	0.30 ± 0.10	NA
Rear stance	0.00 ± 0.06	0.10 ± 0.06	0.13 ± 0.06	−0.02 ± 0.06	0.04 ± 0.10

[1] Evaluated as per Stock et al. (2017) using an objective method based on digital images.

[2] NA = not applicable; model did not converge.

Table 6. Linear model heritability estimates (±SE; multitrait) and genetic correlation (±SE; multitrait) estimates for objectively measured[1] feet and leg angle between selection and post first parity in replacement females

Traits	Heritability at selection	Heritability post first parity	Genetic correlation
Knee	0.21 ± 0.09	0.30 ± 0.10	0.91 ± 0.20
Front pastern	0.19 ± 0.10	0.31 ± 0.09	0.99 ± 0.01
Rear pastern	0.33 ± 0.10	0.26 ± 0.10	0.18 ± 0.27
Hock	0.25 ± 0.10	0.32 ± 0.10	−0.06 ± 0.29
Rear stance	NA[2]	NA	NA

[1] Evaluated as per Stock et al. (2017) using an objective method based on digital images.

[2] NA = not applicable; model did not converge.

0.18, respectively), with SE indicating they are not different than zero.

DISCUSSION

The different feet and leg conformation traits included in the present study were chosen as they have been reported to be associated with sow longevity. For instance, soft (or often referred to as weak) front pasterns are associated with improved sow longevity (Grindflek and Sehested, 1996; Jorgensen, 1996; Stalder et al., 2004). Alternatively, several studies have reported a negative association between sow longevity and buck knees, straight rear legs, and upright rear pasterns (Jorgensen, 1996; Stalder et al., 2004; Tiranti et al., 2006; Fernàndez de Sevilla, 2008). However, there is limited research regarding feet and leg conformation changes over time.

To our knowledge, there is only one study (Fernàndez de Sevilla et al., 2009) that has previously documented changes in feet and leg conformation within the same animal over time. Using a visual subjective feet and leg conformation scoring system, Fernàndez de Sevilla et al. (2009) studied six feet and leg conformation defect traits and an overall conformation score on the front and rear legs of 436 replacement and breeding females to identify feet and leg deficiency prevalence at three time points (end of growing period, first farrowing, second farrowing). Four traits from the previous work (splay-footed, straight pastern, sickle-hocked leg, and overall score) are similar to traits evaluated in the present study. Fernàndez de Sevilla et al. (2009) observed that prevalence of splay footedness became greater between the end of growing period and first parity for both Landrace and Large White purebred females. Likewise, the presence of sickled hocked rear leg became more prevalent with age for both Landrace and Large White females. The same study reported that the prevalence of straight pasterns was greater between the end of the grower period and first parity for Large White females. Fernàndez de Sevilla et al. (2009) concluded that the overall conformation score in both breeds decreased over each of the three time points evaluated. However, the results from the present study disagree with the previous findings. It is difficult to directly compare the evaluation procedures from the current study and those used in the study from Fernàndez de Sevilla et al. (2009), because the previous work directly scored defects as absent/present and overall conformation score on a scale of zero to two, whereas the current study did not directly score leg defects but measured each joint individually as an angle value. The contradiction between Fernàndez de Sevilla et al. (2009) and the present study occurs in both the hock and in the pastern angles. Decreased hock angulation (sickle hocked) became more prevalent over time in Fernàndez de Sevilla et al. (2009), however, in the present study it was observed that the hock became straighter. Pasterns became straighter (more angulation) in the work performed by Fernàndez de Sevilla et al. (2009), whereas the present findings observed both front and rear pasterns became softer (less angulation) as the animals aged. Currently, we have not developed an overall conformation score based on objectively measured feet and leg angles. However, based on previous studies regarding sow longevity and feet and leg traits, the results from the present study suggest that an overall conformation score based on objectively measured traits would improve as the replacement females became older.

Of interest is the levels at which joint angles change and the time frame and potential causes for those changes. For that reason, we chose to conduct two separate analyses using the entire population first and then with a reduced population as described previously. The results show that estimates, in both analyses, are almost identical in terms of change between selection and post first parity. This would indicate that feet and leg joint angle changes take place at some point before the sow weans their first litter. Furthermore, to identify feet and leg joint changes during the gestation process, gestation week during second gestation was examined. While the front pastern does get softer, these results agree with the parity findings where joint changes were greater within replacement females prior to first litter weaning. It is unclear whether added weight was a factor resulting in joint angle changes in the present study because body weight was not recorded during the replacement females' second measurement. However, research has been conducted in humans attempting to determine the impact that the hormone relaxin, during pregnancy through parturition, have on joint laxity. For instance, Calguneri et al. (1982), Marnach et al. (2003), and Schauberger et al. (1996) observed increased joint laxity during pregnancy but they found no association between relaxin levels and joint laxity. However, Marnach et al. (2003) did subsequently find an association between wrist flexion-extension laxity and maternal cortisol levels. Calguneri et al. (1982) reported that while relaxin was not correlated with joint laxity, joint laxity was greater during the third trimester of pregnancy and consequently was greater in women having their second child when compared to women having their first child, with no further change in women having their third or greater pregnancies. The present study had limited animals in what would be considered the sow's third trimester of their first pregnancy and therefore cannot attempt to reproduce the same test in pigs at this time.

Farm effects on joint angle differences are difficult to explain. However, it is likely that the observed differences are due to management and environmental factors as similar genetic lines were used across farms. Fatehi et al. (2003) reported environmental differences in feet and leg conformation evaluated in dairy cows under several different environments. The three farms in the present study, that the original population of replacement females was divided among, were all similar in design (single gestation crated), served similar ration, and had no obvious apparent differences between the equipment used in each farm. Therefore, determining what if any environmental factors play a significant role in the feet and leg differences observed in this study cannot be made and warrant further investigation. It may be possible that other factors like management, production level, nutrition, and other environmental issues played a role in the feet and leg joint angle differences observed in the present study.

To our knowledge, this is the first time that heritability has been estimated when the traits have been evaluated using an objective measuring system. The present findings are similar to those reported for subjective measurement by Bereskin (1979), Rothschild and Christian (1988), Serenius et al. (2001), and Fan et al. (2009) where heritability estimates are low to moderate for the joints evaluated. Genetic correlations above 0.8 between the same joints at time of selection and post first parity indicate that the two time points can be treated as the same trait; however, genetic correlations under 0.8 indicate that the two time period measures need to be treated as separate traits (Robertson, 1959). The statistical differences observed among joints across time periods in the present study coincide with the genetic correlation estimates between time points of selection and post first parity.

Summary and Implications

Results from the present study suggest that feet and leg conformation traits change in both front and rear legs between selection and post first parity. The changes in the rear leg were in a direction that could improve sow longevity and sow productive lifetime as the hock became less angular (away from sickled) and the rear pastern became softer. According to these differences and the low genetic correlation between the same trait across two time points in the rear leg, it may be necessary to evaluate each sow post first parity to effectively understand how their offspring will perform. This time represents a short period and studies have shown that females continue to grow until they reach approximately the third parity or later (Robison, 1976). Further research is necessary to understand the rear feet and leg changes that occur from selection until the end of the gilts' growth cycle. Likewise, the range of acceptable starting values or scores for replacement females at selection needs to be determined for the various feet and leg traits, so that after conformation changes occur as the animals age, desirable feet and leg conformation remains as the animals progress through their older parities. If this remains true into the sow's later parities, objective angle evaluation could be incorporated in selection programs early in the replacement female's life to improve feet and leg conformation and to help increase sow longevity/sow lifetime productivity which ultimately improves producer's production efficiency and profitability.

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