Animal (2012), **6:1**, pp 1–8 © The Animal Consortium 2011
doi:10.1017/S1751731111001170

Heritability of shoulder ulcers and genetic correlations with mean piglet weight and sow body condition

H. Lundgren[1†], B. Zumbach[2], N. Lundeheim[1], K. Grandinson[1], O. Vangen[3], D. Olsen[4] and L. Rydhmer[1]

[1]Department of Animal Breeding and Genetics, Swedish University of Agricultural Sciences, Box 7023, 750 07 Uppsala, Sweden; [2]Interbull Center, Department of Animal Breeding and Genetics, Swedish University of Agricultural Sciences, Box 7023, 750 07 Uppsala, Sweden; [3]Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences, P.O. Box 5003, 1432 Aas, Norway; [4]Norsvin, P.O. Box 504, 2304 Hamar, Norway

(Received 10 July 2010; Accepted 12 May 2011; First published online 26 July 2011)

The objective of this paper was to estimate the heritability for shoulder ulcers and the genetic correlations between shoulder ulcers, mean piglet weight and sow body condition. The analyses were based on information on 5549 Norwegian Landrace sows and their 7614 purebred litters. The genetic analysis was performed using the Gibbs sampling method. Shoulder ulcers were analyzed as a threshold trait. Sow body condition and mean piglet weight were analyzed as linear traits. The heritability of shoulder ulcers was estimated at 0.25 (s.d. = 0.03). The heritability for sow body condition was estimated at 0.14 (s.d. = 0.02) and that for mean piglet weight at 0.23 (s.d. = 0.02). The genetic correlation between shoulder ulcers and sow body condition was negative (−0.59, s.d. = 0.09). The genetic correlation between shoulder ulcers and mean piglet weight was positive (0.23, s.d. = 0.10) and the genetic correlation between sow body condition and mean piglet weight was negative (−0.24, s.d. = 0.10).

Keywords: decubital ulcers, shoulder sores, skin lesions, pig breeding, welfare

Implications

Shoulder ulcers are a heritable trait. The estimated genetic parameters of shoulder ulcers and the association to mean piglet weight and sow body condition can be used in the design of breeding programs to reduce the presence of shoulder ulcers.

Introduction

Shoulder ulcers in sows are a welfare problem (Broom, 1988; Herskin *et al*., 2010). The incidence rate of shoulder ulcers among sows in pig production varies between 10% and 34% in studies based on farm data as well as on information from slaughter houses (Baustad and Fredriksen, 2006; Zurbrigg, 2006; Knauer *et al*., 2007; Bonde, 2008; Ivarsson *et al*., 2009; KilBride *et al*., 2009). Shoulder ulcers appear when the tissue is under pressure between a surface and the tuber of the scapular spine for a longer time, or repeatedly without enough time in between for the tissue to recover from the resulting ischemia (Jensen, 2009). These ulcers are believed to cause varying levels of pain in the different stages, and they are also an entrance for pathogens causing infections (Herskin *et al*., 2010). Costs for shoulder ulcers are generated by treatments, reduced carcass value due to total or partial condemnation and replacement of culled sows with gilts (Gunnar Johannsson, personal communication, 2010; Swedish Animal Health Service, Sweden). Sows should be kept for at least three parities in order to be economically profitable (Stalder *et al*., 2003).

As reviewed by Bonde *et al*. (2007), the etiology for shoulder ulcers is multifactorial. Many environmental factors influence the prevalence and severity of shoulder ulcers, such as flooring (Bonde *et al*., 2004; Ivarsson *et al*., 2009) and feeding routines (Sørensen, 2009). Pen size and design, indoor/outdoor temperature and humidity (e.g. drip coolers) may also increase the risk of developing shoulder ulcers (Bonde *et al*., 2007). Other factors are more sow related. Individual variation in body conformation such as differences in the shoulder blade anatomy might play a role (Agerley *et al*., 2007). Shoulder ulcers in previous lactations increase the risk of new ulcers (Kaiser *et al*., 2006). Older sows are usually larger compared with younger animals, and the reduced space due to the larger size of the older sow may hinder her from posture changes (McGlone *et al*., 2004). Greater weight leads to more pressure on critical areas, for example, the shoulders (Le *et al*., 1984). Older sows have

† E-mail: Helena.Lundgren@hgen.slu.se

also been exposed to environmental risk factors for a longer time than sows in early parities (Kaiser *et al.*, 2007). On the other hand, when sows are group fed, older sows usually maintain a better body condition due to a higher rank in the group (Brouns and Edwards, 1994; Kranendonk *et al.*, 2007; Hoy *et al.*, 2009). Health status and stress response are other factors that could influence the presence of shoulder ulcers (Bonde *et al.*, 2007). Poor sow body condition in the time period around farrowing and lactation increases the risk of developing shoulder ulcers (Davies *et al.*, 1997; Bonde *et al.*, 2004; Zurbrigg, 2006; Knauer *et al.*, 2007; Ivarsson *et al.*, 2009). Over the last decades, there has been a systematic selection for leanness (de Vries and Kanis, 1994; Edwards, 1998), that is, against the ability to build up body reserves.

The objective of this paper was to estimate the heritability for shoulder ulcers and the genetic correlations between shoulder ulcers, mean piglet weight at 3 weeks and sow body condition at weaning.

Material and methods

Data and editing of data

Animal Care and Use approval was not needed because the data used in this study were obtained from an existing database. Data were extracted from the Norwegian litter recording scheme, provided by the Norwegian pig breeding company, Norsvin, and recorded between January 2008 and April 2010. All recordings were made by the farmer or herdsman who was instructed by breeding technicians on how to score shoulder ulcers and sow body condition. Shoulder ulcers and sow body condition were recorded at weaning. Shoulder ulcers were scored on a scale from 0 to 4 (Animalia, 2010). The description of the scores that the farmers use is as follows: 0 = no ulcers, 1 = ulcers in the epidermal layer of the skin and sometimes with crust formation, 2 = ulcers in the epidermal/dermal layer of the skin with crust formation and scar tissue, 3 = ulcers in the subcutical layer of the skin and with crust formation and 4 = deep ulcers into the muscles, sometimes with visible shoulder bone. Histological examinations were not performed. Sow body condition was scored on a scale from very thin (1) to very fat (9; Norsvin, 2010). Individual piglets were weighed between 17 and 25 days of age, an interval recommended by the breeding company. Weights recorded outside this interval were regarded as missing values in the analyses. Moreover, weight records outside the interval of the uncorrected mean $\pm$ 3 s.d. (rounded upward, i.e. 2 to 13 kg) were regarded as missing values. The mean piglet weight was calculated from the individual weights of the piglets in the litter. Lactation length was limited to an interval between 17 and 49 days. Litters with a lactation length outside the interval were excluded from the data set. Herds with fewer than 30 litters during the time of data collection were excluded from the data set as well as one herd with no recorded shoulder ulcer scores of 1 to 4.

The sows were loose housed in individual farrowing pens during the entire lactation period. The sows were given dry feed, wet feed or wet feed with dry feed as a complement. When using wet feed, the feed pellets were mixed with water or whey. In general, sows were fed restrictively in the beginning of the lactation period. The recommendation is to give the sow 17.6 MJ net energy/day on the day of farrowing. The amount of feed given is increased by +8.8 MJ/day according to appetite. In the third week of lactation, the recommendation says that sows (if healthy) should be fed so that they can consume feed *ad libitum*. This is approximately between 70 and 106 MJ net energy/day. The sow feed contains approximately 10 MJ/kg dry matter. The number of feedings per day varies from 2 to 4 (Solveig Kongsrud, personal communication, 2010; Norsvin, Norway).

After editing, the data set contained information on 5549 Norwegian Landrace sows and their 7614 purebred litters. In 74.2% of the lactations, the sows developed no shoulder ulcer (score 0). During 15.1% of all lactations, sows were given a score of 1, during 7.5% a score of 2, during 2.9% a score of 3 and during 0.3% a score of 4 for shoulder ulcers. Descriptive statistics for the traits included in the genetic analysis are presented in Table 1. Owing to few observations for the higher scores of shoulder ulcers, the trait was categorized into two classes. Animals without shoulder ulcers were given score 1 and animals with shoulder ulcers were given score 2. Of the 1599 sows with several parities in the data set, 13.6% had shoulder ulcers more than once. The incidence of shoulder ulcers in consecutive parities are presented in Table 2.

All together, 45 Norwegian herds were represented in the data set. Out of these herds, 36 were nucleus herds (n = 5073 observations), 6 were multiplier herds (n = 356) and 3 were commercial herds (n = 120). The parity of the sows ranged from 1 to 8 and was in the analyses classified into three categories (1 for 1st parity sows, 2 for 2nd parity

Table 1 *Descriptive statistics for the sow traits in the genetic analysis made on 5549 Norwegian Landrace sows (7614 lactations) in 45 herds recorded between January 2008 and April 2010*

Traits	n	Mean	s.d.	Min	Max
Shoulder ulcers[1]	7614	1.3	–	1 (74.2%)	2 (25.8%)
Sow body condition[2] (score)	7561	4.2	1.04	1	9
Mean piglet weight[3] (kg)	7614	7.1	1.26	3.2	12.9

[1]1 = no shoulder ulcers at weaning and 2 = shoulder ulcers at weaning.
[2]Sow body condition was scored on a scale from 1 to 9 (from 1 = very thin to 9 = very fat) at weaning.
[3]Mean piglet weight was calculated from the individual weights of the piglets in the litter at 3 weeks.

sows and 3 for sows in 3rd parity or older) as the number of sows in parities above 3 was low. The number of observations in the different parities and the frequency of sows grouped in 1st, 2nd or 3rd parity is presented in Table 3.

Average lactation length, 35 days (s.d. = 5.9), corresponded well to the lactation length of an average herd in Norway (Norsvin, 2010). The number of piglets born alive was on average 12.5 (s.d. = 3.24) and the number of piglets weaned was on average 10.5 (s.d. = 2.34). In nucleus herds, approximately 10% of the piglets are cross fostered according to the breeding organization (Norsvin, 2010). As the recordings of nursing sows to which piglets were entrusted were incomplete, cross fostering was ignored in the analyses. The pedigree was traced five generations back when possible and the final pedigree file included 9783 animals. In the studied herds, there was a 100% use of artificial insemination (AI) and the herds were genetically connected through the use of the same AI boars.

Table 2 *Number of times shoulder ulcers[1] were observed in consecutive parities for 5549 Norwegian Landrace sows in 45 herds recorded between January 2008 and April 2010*

	Number of monitored parities per sow				
Number of times	1	2	3	4	5
Never	2946	687	175	20	1
Once	1004	376	100	19	4
Twice	–	140	42	10	3
Three times	–	–	17	3	–
Four times	–	–	–	2	–

[1]Description of the scoring of shoulder ulcers at weaning: 0 = no ulcers, 1 = ulcers in the epidermal layer of the skin and sometimes with crust formation, 2 = ulcers in the epidermal/dermal layer of the skin with crust formation and scar tissue, 3 = ulcers in the subcutical layer of the skin and with crust formation and 4 = deep ulcers into the muscles, sometimes with visible shoulder bone.

Table 3 *Distribution of observations[1] between parities*

Parity number	1	2	3	4	5	6	7	8
Observations	4582	1889	784	269	68	17	4	1
Frequency (%)	60	25	15[2]					

[1]Data from 5549 Norwegian Landrace sows (7614 lactations) in 45 herds recorded between January 2008 and April 2010.
[2]Includes all observations from 3rd to 8th parity.

Both phenotypic and genetic analyses of the traits in focus for this study were performed. Sow body condition and mean piglet weight were analyzed as linear traits. Shoulder ulcers was analyzed as a binary trait in the phenotypic analysis and as a threshold trait (Gianola, 1982) in the genetic analysis. Distributions for the traits shoulder ulcers and sow body condition are presented in Figure 1.

Phenotypic analyses

Phenotypic single-trait analyses were performed with the SAS software, version 9.1 (SAS Institute Inc., Cary, NC, USA). The significance of the effects of season and parity on shoulder ulcers were obtained with PROC GLIMMIX, using a binary distribution with a logit link function. The correlations between repeated observations within a sow were handled by specifying the compound symmetry covariance structure with sow as the subject. PROC GLIMMIX was assumed to have converged when the absolute change in parameter estimates between successive iterations was less than 1e−6. The following model was used for shoulder ulcers:

$$\operatorname{log\,it}(Pr[Y_{ijklm} = 0]) = \mu + h_i + s_j + p_k + b_1 \times 1_{ijklm} + b_2 \times 2_{ijklm}$$

where Y_{ijklm} = shoulder ulcers, μ = general mean, h_i = fixed effect of the ith herd, s_j = fixed effect of the jth season, p_k = fixed effect of the kth parity, $b_1 \times 1_{ijklm}$ = regression on number of piglets weaned and $b_2 \times 2_{ijklm}$ = regression on lactation length.

Least square (LS) means for the effect of season and parity on sow body condition and mean piglet weight were obtained with PROC MIXED. For mean piglet weight, the following model was used: $Y_{ijklm} = \mu + h_i + s_j + p_k + b_1 \times 1_{ijklm} + b_2 \times 2_{ijklm} + a_{ijkl} + e_{ijklm}$, where Y_{ijklm} = mean piglet weight, $b_1 \times 1_{ijklm}$ = regression on number of piglets at weighing, $b_2 \times 2_{ijklm}$ = regression on age (days) of the

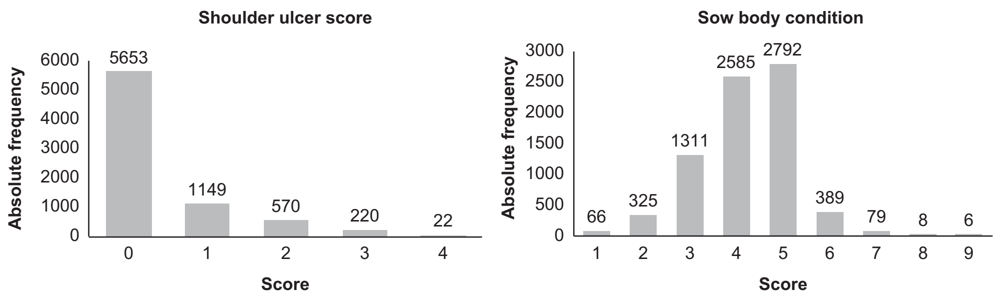

Figure 1 Shoulder ulcers[1] and sow body condition[2] distributions in Norwegian Landrace sows[3]. ([1]Description of the scoring of shoulder ulcers at weaning: 0 = no ulcers, 1 = ulcers in the epidermal layer of the skin and sometimes with crust formation, 2 = ulcers in the epidermal/dermal layer of the skin with crust formation and scar tissue, 3 = ulcers in the subcutical layer of the skin and with crust formation and 4 = deep ulcers into the muscles, sometimes with visible shoulder bone. [2]Sow body condition was scored on a scale from 1 to 9 (from 1 = very thin to 9 = very fat) at weaning. [3]Data from 5549 Norwegian Landrace sows (7614 lactations) in 45 herds registered between January 2008 and April 2010.)

piglets at weighing, a_{ijkl} = random animal effect and e_{ijklm} = random residual effect. In the model used for sow body condition, $b_1 \times 1_{ijklm}$ = regression on number of piglets weaned and $b_2 \times 2_{ijklm}$ = regression on lactation length. The season used in the phenotypic analyses was the season of farrowing for all traits, and the season component in the phenotypic analyses corresponds to the year divided into quarters; January to March, April to June, July to September and October to December.

Genetic analysis

The genetic analysis was performed using the Gibbs sampling method with the program THRGIBBS1F90 developed by Tsuruta and Misztal (2006). The post-Gibbs analysis was performed using the program POSTGIBBSF90 (Misztal *et al.*, 2002). The total number of iterations was set to 500 000. The burn-in period was set to 50 000 iterations after graphical inspection of the plots of the sampled values *v.* iterations as proposed by Kass *et al.* (1998). Every 50th sample was saved and a total of 9000 samples were included in the post-Gibbs analysis. Incidence of shoulder ulcers, mean piglet weight and sow body condition were analyzed by multitrait animal models. The following model was used for shoulder ulcers:

$$\text{probit}([Y_{ijklm} = 0]) = \mu + h_i + ys_j + p_k + b_1 \times 1_{ijklm} + b_2 \times 2_{ijklm} + \text{pe}_{ijkl} + a_{ijkl}$$

where Y_{ijklm} = shoulder ulcers or sow body condition, μ = general mean, h_i = fixed effect of the *i*th herd, ys_j = fixed effect of the *j*th year × month combination, p_k = fixed effect of the *k*th parity, $b_1 \times 1_{ijklm}$ = regression on number of piglets weaned, $b_2 \times 2_{ijklm}$ = regression on lactation length, pe_{ijkl} = random permanent environmental effect and a_{ijkl} = random animal genetic effect.

For mean piglet weight, the following model was used: $Y_{ijklm} = \mu + h_i + ys_j + p_k + b_1 \times 1_{ijklm} + b_2 \times 2_{ijklm} + \text{pe}_{ijkl} + a_{ijkl} + e_{ijklm}$, were Y_{ijklm} = mean piglet weight, $b_1 \times 1_{ijklm}$ = regression on number of piglets at weighing, $b_2 \times 2_{ijklm}$ = regression on age (days) of the piglets at weighing and e_{ijklm} = random residual effect. In the model used for sow body condition, $b_1 \times 1_{ijklm}$ = regression on number of piglets weaned and $b_2 \times 2_{ijklm}$ = regression on lactation length. The month used in the year × month combination was the month of farrowing for all traits. Owing to few observations in some months, the observations were sometimes grouped. The phenotypic variance was calculated from each of the saved samples as $\sigma_p^2 = \sigma_a^2 + \sigma_{pe}^2 + \sigma_e^2$. The heritability was calculated as σ_a^2/σ_p^2 and the repeatability as $(\sigma_a^2 + \sigma_{pe}^2)/\sigma_p^2$.

Results

Phenotypic analysis

The effect of herd on shoulder ulcers was significant ($P < 0.0001$). In one of the herds, only 2% of the sows were affected compared with >50% of the sows in the herds with the highest frequencies of shoulder ulcers. There was a significant effect of farrowing season on shoulder ulcers ($P = 0.0004$). From July to September, 29% of the sows had shoulder ulcers, compared with an average of 24% for the other quarters. Lactation length had a significant effect on shoulder ulcers ($P < 0.0001$). Sows with longer lactation length had a greater risk of developing shoulder ulcers. There was also a significant effect of number of piglets weaned on shoulder ulcers ($P < 0.0001$); sows with large litters were more affected. First-parity sows had less shoulder ulcers, lower body condition and lower mean piglet weight than older sows (Table 4).

Genetic analysis

Variance component estimates and effective sample sizes are presented in Table 5. The effective sample size for the estimated variance components varied from 80 to 4428. The repeatabilities were 0.36, 0.25 and 0.28 for shoulder ulcers, sow body condition and mean piglet weight, respectively. Heritability and correlation estimate distributions are presented in Figures 2 and 3, respectively. The differences between mean, mode and median values of each estimate were all very small. The environmental correlation between shoulder ulcers and sow body condition was −0.37 (s.d. = 0.03). The environmental correlation between shoulder ulcers and mean piglet weight was −0.04 (s.d. = 0.03) and between sow body condition and mean piglet weight 0.10 (s.d. = 0.02).

Discussion

Considerable work has been performed to describe the effect of environmental and biological factors on shoulder ulcers

Table 4 *Frequency of sows[1] without shoulder ulcers at weaning, sow body condition and mean piglet weight least square means[2] by parity[3]*

Trait	Parity: 1st, $n = 4582$	2nd, $n = 1889$	3rd, $n = 1143$
Sows without shoulder ulcers (%)	78^a	68^b	69^b
Sow body condition[4] (score)	4.1^a	4.3^b	4.5^c
Mean piglet weight[5] (kg)	6.86^a	7.65^b	7.52^c

[1]Data from 5549 Norwegian Landrace sows (7614 lactations) in 45 herds registered between January 2008 and April 2010.
[2]Values with different superscripts within row differ significantly ($P < 0.05$).
[3]3rd parity includes parity 3 to 8.
[4]Sow body condition was scored on a scale from 1 to 9 (from 1 = very thin to 9 = very fat) at weaning.
[5]Mean piglet weight was calculated from the individual weights of the piglets in the litter at 3 weeks.

Table 5 *Shoulder ulcers, sow body condition and mean piglet weight variance component estimates[1] from Norwegian Landrace sows[2]*

Trait	Variance components[3] and effective sample size (n_e)					
	σ_a^2	n_e	σ_{pe}^2	n_e	σ_e^2	n_e
Shoulder ulcers[4]	$0.40_{0.07}$	859	$0.17_{0.05}$	80	$1.01_{0.02}$	4428
Sow body condition[5]	$0.10_{0.02}$	457	$0.08_{0.02}$	280	$0.55_{0.02}$	761
Mean piglet weight[6]	$0.20_{0.02}$	663	$0.04_{0.02}$	171	$0.63_{0.02}$	945

[1]Estimated variance components with posterior s.d. as subscript and effective sample size for the traits shoulder ulcer, body condition at weaning and mean piglet weight.
[2]Data from 5549 Norwegian Landrace sows (7614 lactations) in 45 herds recorded between January 2008 and April 2010.
[3] σ_a^2 = additive genetic variance, σ_{pe}^2 = permanent environmental variance and σ_e^2 = residual variance.
[4]Categorized as no shoulder ulcers (1) or shoulder ulcers (2) at weaning.
[5]Sow body condition was scored on a scale from 1 to 9 (from 1 = very thin to 9 = very fat) at weaning.
[6]Mean piglet weight was calculated from the individual weights of the piglets in the litter at 3 weeks.

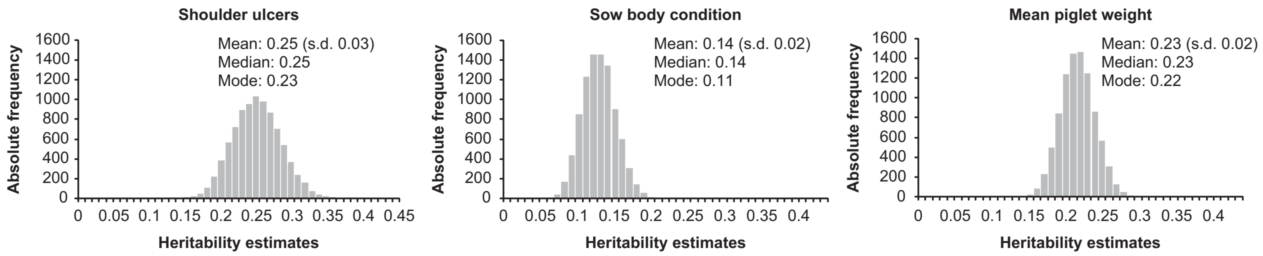

Figure 2 Marginal posterior distribution of heritability estimates for shoulder ulcers[1], sow body condition[2] and mean piglet weight[3] from Norwegian Landrace sows[4]. ([1]1 = no shoulder ulcers at weaning, 2 = shoulder ulcers at weaning. [2]Sow body condition was scored on a scale from 1 to 9 (from 1 = very thin to 9 = very fat) at weaning. [3]Mean piglet weight was calculated from the individual weights of the piglets in the litter at 3 weeks. [4]Data from 5549 Norwegian Landrace sows (7614 lactations) in 45 herds recorded between January 2008 and April 2010.)

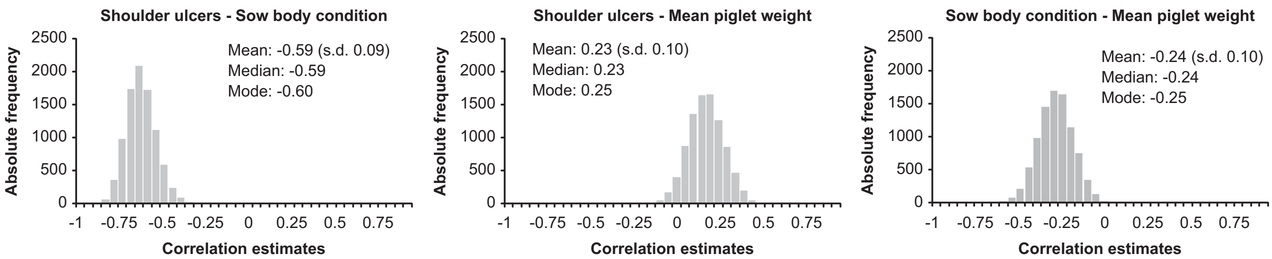

Figure 3 Marginal posterior distribution of genetic correlation estimates for shoulder ulcers[1], sow body condition[2] and mean piglet weight[3] from Norwegian Landrace sows[4]. ([1]1 = no shoulder ulcers at weaning, 2 = shoulder ulcers at weaning. [2]Sow body condition was scored on a scale from 1 to 9 (from 1 = very thin to 9 = very fat) at weaning. [3]Mean piglet weight was calculated from the individual weights of the piglets in the litter at 3 weeks. [4]Data from 5549 Norwegian Landrace sows (7614 lactations) in 45 herds recorded between January 2008 and April 2010.)

(Davies *et al.*, 1997; Bonde *et al.*, 2004; Cleveland-Nielsen *et al.*, 2004; Rolandsdotter *et al.*, 2009). To our knowledge, only few attempts have been made to estimate genetic parameters of shoulder ulcers (Bradley, 2005). Thus the following discussion, if not stated otherwise, includes comparisons with results from phenotypic studies.

The phenotypic analysis in the present study showed that the frequency of shoulder ulcers was 5 percentage points greater during July to September than during the rest of the year. This could be due to several reasons, such as increased lying bouts and lower feed intake due to increased temperature in the stable (Bonde *et al.*, 2007). The data set for this study consisted of purebred Norwegian Landrace sows. In a Canadian study, Landrace and Duroc sows were more likely to develop shoulder ulcers than Yorkshire sows (Zurbrigg, 2006). When comparing the three breeds, Zurbrigg (2006) found that the risk of developing shoulder ulcers was 3.0 times greater for Landrace sows and 4.6 times greater for Duroc sows, as compared with Yorkshire sows. Breed combination in crossbred sows may also have an effect on the presence of shoulder ulcers (Bonde *et al.*, 2007). Anatomical, physiological (e.g. stress response, immune response), as well as behavioral differences, may explain some of the variation in shoulder ulcers between breeds. Further studies of breed effects on shoulder ulcers could be of value for the pig production industry in the choice of breed combinations.

Ivarsson *et al*. (2009) reported that the development of shoulder ulcers increased from the 4th to the 5th lactation week. Furthermore in the present study, there was a significant effect of lactation length on the incidence of shoulder ulcers. As there is a parent–offspring conflict linked to lactation length (Bøe, 1991), it would be interesting to study more specifically when the shoulder ulcers appear and the effect of lactation length.

The heritability for shoulder ulcers was estimated at 0.25 on the underlying scale. This can be considered as a high value as the measure of the trait shoulder ulcers was relatively rough. In this study, we did not use all the available information from the recordings, as we used an affected/not affected approach in the analysis. The goal in pig production should be 'no sows with shoulder ulcers in the herds', which could justify this simplification. The heritability of body condition was estimated at 0.14 in this study. Grandinson *et al*. (2005) estimated heritability of backfat loss (ultrasonic measurement) and weight loss during lactation at 0.10 and 0.20, respectively, using data from an experimental herd. Borg *et al*. (2009) estimated heritabilities for body condition in ewes and these results were similar to the present findings. In their study, heritability for body condition during lactation was estimated at 0.13 and after weaning the lambs at 0.15. The heritability estimate for mean piglet weight in this study (0.23) was comparable with previously published reports (Högberg and Rydhmer, 2000) and previous estimates from the Norwegian Landrace population (Canario *et al*., 2010; Lundgren *et al*., 2010).

In this study, the genetic correlation between mean piglet weight and body condition was negative (−0.24). This is lower than the correlation reported by Grandinson *et al*. (2005), who estimated the genetic correlation between loss in body weight during lactation and piglet growth to −0.85 using data from a research herd. Milk production is costly for the sow and a large, heavy litter can result in poor sow body condition as a consequence of the sow utilizing body tissue reserves (Valros *et al*., 2003; Grandinson *et al*., 2005). The genetic correlation between shoulder ulcers and sow body condition was also negative (−0.59). Sows with poor body condition have an increased risk of developing shoulder ulcers. This fact is well documented on a phenotypic level in the literature (Davies *et al*., 1997; Bonde *et al*., 2004; Zurbrigg, 2006; Knauer *et al*., 2007; Ivarsson *et al*., 2009). The genetic correlation between shoulder ulcers and mean piglet weight was low but positive and thus unfavorable (0.23). The genetic ability to raise heavy piglets increases the risk of shoulder ulcers. This is in agreement with the phenotypic study by Zurbrigg (2006), which showed that increased litter weaning weight increases the risk of developing shoulder ulcers. In general, high-producing sows are definitely more at risk of developing shoulder sores than sows with a lower production.

In the present findings, 1st parity sows had lower body condition score at weaning compared with older sows. First-parity sows are not able to consume a sufficient quantity of food in order to fully compensate for the high-energy requirements during lactation (Eissen *et al*., 2000). The body resources available for production and reproduction are limited, and there is a trade-off between different processes in an animal such as maintenance, own growth, reproduction or growth of offspring (Beilharz *et al*., 1993). Thus, there is a conflict concerning nutrient allocation between the needs of a sow's current litter and the sow's own needs. Indeed, besides resources for milk production, the young sow is still growing (Whittemore, 1996). In the present findings, there was a significant effect of litter size at weaning on shoulder ulcers. Litter size was lower in 1st parity sows than in later parities (10.6 piglets *v*. 11.1 piglets at weaning, results not shown). However, the incidence of shoulder ulcers from 1st parity sows was significantly lower when compared with older sows, even when the correction for litter size was applied to the model. This could be related to the fact that older sows raise heavier piglets, or maybe to aging in itself or longer exposure to unfavorable environmental effects.

Shoulder ulcers are more common in sows with leg disorders (Bonde *et al*., 2004; Knauer *et al*., 2007), and post-partum dysgalactia syndrome is known to increase the risk of developing shoulder ulcers (Ivarsson *et al*., 2009). Selection for robust pigs may thus decrease the risk of shoulder ulcers. Both inferior health and stress may increase the time sows spend lying down (Bonde *et al*., 2007) and increased time lying down increases the risk of developing shoulder ulcers (Rolandsdotter *et al*., 2009).

In all Scandinavian countries, shoulder ulcers is a large part of the sow welfare discussion and action plans against shoulder ulcers are developed (Ministry of Food, Agriculture and Fisheries, Denmark; Animalia, Norway; Swedish Animal Health Service, Sweden). However, the conditions differ when it comes to the legal ramifications. In Denmark, fines and jail terms are imposed for marketing sows with shoulder ulcers (Dyrevaernsloven, retsinformation.dk; Ministry of Food, Agriculture and Fisheries, Denmark). In total, 619 cases have been reported to the police during 2004 to 2009 (Mousing *et al*., 2008). Focus has been on estimating genetic parameters for shoulder ulcers in this study, but in a longer perspective the aim is to decrease the frequency of shoulder ulcers by selection. An economic weight has to be calculated before shoulder ulcers can be included in a genetic evaluation. Economic costs of treatments, extra work, extra replacement of sows and loss of carcass value can be calculated. The costs of low pig welfare and possible losses due to consumers' mistrust in pork production are more difficult to predict (Olesen *et al*., 2000). More weight on traits important for sow welfare included in the genetic evaluation will slow down the progress in production traits (Gourdine *et al*., 2010), and this cost should also be taken into account. One way forward is to define an economic weight by the desired-gains approach as suggested by Kanis *et al*. (2005). In the first step, this desired gain could be no further deterioration of shoulder health.

Conclusions

Shoulder ulcers in lactating sows are heritable and sows producing heavier piglets have a higher risk of developing shoulder ulcers when compared with other sows. Owing to the genetic correlations between shoulder ulcers and mean piglet weight as well as sow body condition, it is important to take into account shoulder ulcers in breeding programs in order to improve sow welfare and to avoid associated economic losses.

Acknowledgements

This study was financed by the Swedish Farmers' Foundation for Agricultural Research (SLF). Data were provided by The Norwegian Pig Breeders Association (Norsvin). We thank Freddy Fikse for valuable advice. Last but not least, the authors would like to thank the farmers for their contribution through the work with the recordings.

References

Agerley M, Høgedal P and Pedersen B 2007. Pilot project concerning examination of the shoulder blade in sows with or without shoulder ulcers (in Danish). Nyhedsbrevet PigVet. Retrieved November 20, 2010, from http://www.pigvet.dk/secure/hudsygd.htm

Animalia. Postboks 396 – Økern, 0513 Oslo, Norway (www.animalia.no).

Baustad BM and Fredriksen B 2006. Prevalence and prevention of decubital shoulder ulcers in Norwegian sows. Proceedings of the International Pig Veterinary Society Congress, 16–19 July, Copenhagen, Denmark.

Beilharz RG, Luxford BG and Wilkinson JL 1993. Quantitative genetics and evolution – is our understanding of genetics sufficient to explain evolution. Journal of Animal Breeding and Genetics – Zeitschrift fur Tierzuchtung und Zuchtungsbiologie 110, 161–170.

Bøe K 1991. The process of weaning in pigs: when the sow decides. Applied Animal Behaviour Science 30, 47–59.

Bonde M 2008. Prevalence of decubital shoulder lesions in Danish sow herds (in Danish). Internal Report 12, Faculty of Agricultural Sciences, University of Aarhus, 8 pp.

Bonde M, Rousing T, Badsberg JH and Sørensen JT 2004. Associations between lying-down behaviour problems and body condition, limb disorders and skin lesions of lactating sows housed in farrowing crates in commercial sow herds. Livestock Production Science 87, 179–187.

Bonde M, Herskin MS, Jørgensen E and Hjelholt Jensen K 2007. Knowledge synthesis of shoulder ulcers in sows (in Danish). DJF Husdyrbrug nr 81. Aarhus University, Tjele, Denmark.

Borg RC, Notter DR and Kott RW 2009. Phenotypic and genetic associations between lamb growth traits and adult ewe body weights in western range sheep. Journal of Animal Science 87, 3506–3514.

Bradley H 2005. Variation in back conformation and prevalence of ulcers on the shoulders – a cohort study of related Swedish Landrace and Landrace*Yorkshire sows. Master Thesis, No. 270, Department of Animal Breeding and Genetics, Swedish University of Agricultural Sciences.

Broom DM 1988. The scientific assessment of animal welfare. Applied Animal Behaviour Science 20, 5–19.

Brouns F and Edwards SA 1994. Social rank and feeding behavior of group-housed sows fed competitively or ad libitum. Applied Animal Behaviour Science 39, 225–235.

Canario L, Lundgren H, Haandlykken M and Rydhmer L 2010. Genetics of growth in piglets and the association with homogeneity of body weight within litters. Journal of Animal Science 88, 1240–1247.

Cleveland-Nielsen A, Bækbo P and Ersbøll AK 2004. Herd-related risk factors for decubital ulcers present at post-mortem meat-inspection of Danish sows. Preventive Veterinary Medicine 64, 113–122.

Davies PR, Morgan Morrow WE, Rountree WG and Miller DC 1997. Epidemiologic evaluation of decubital ulcers in farrowing sows. Journal of the American Veterinary Medical Association 210, 1173–1178.

de Vries AG and Kanis E 1994. Selection for efficiency of lean tissue deposition in pigs. In Principles of pig science (ed. DJA Cole, J Wiseman and MA Varley), pp. 23–41. Nottingham University Press, UK.

Dyrevaernsloven. Retrieved November 20, 2010, from http://www.retsinformation.dk/Forms/R0710.aspx?id=2714

Edwards SA 1998. Nutrition of the rearing sow and gilt. In Progress in pig science (ed. J Wiseman, MA Varley and JP Chadwick), pp. 361–382. Nottingham University Press, UK.

Eissen JJ, Kanis E and Kemp B 2000. Sow factors affecting voluntary feed intake during lactation. Livestock Production Science 64, 147–165.

Gianola D 1982. Theory and analysis of threshold characters. Journal of Animal Science 54, 1079–1096.

Gourdine JL, de Greef KH and Rydhmer L 2010. Breeding for high welfare in outdoor pig production: a simulation study. Livestock Science 132, 26–34.

Grandinson K, Rydhmer L, Strandberg E and Solanes FX 2005. Genetic analysis of body condition in the sow during lactation, and its relation to piglet survival and growth. Animal Science 80, 33–40.

Herskin MS, Bonde MK, Jørgensen E and Jensen KH 2010. Decubital shoulder ulcers in sows: a review of classification, pain and welfare consequences. Animal, doi:10.1017/S175173111000203X, Published online by Cambridge University Press 22 November 2010.

Högberg A and Rydhmer L 2000. A genetic study of piglet growth and survival. Acta Agriculturae Scandinavica, Section A, Animal Science 50, 300–303.

Hoy S, Bauer J, borberg C, Chonsch L and Weirich C 2009. Investigation on dynamics of social rank of sows during several parities. Applied Animal Behaviour Science 121, 103–107.

Ivarsson E, Mattson B, Lundeheim N and Holmgren N 2009. Shoulder ulcers – prevalence and risk factors (in Swedish). Svenska Pig, Report 42, 8pp.

Jensen HE 2009. Investigation into the pathology of shoulder ulcerations in sows. Veterinary Record 165, 171–174.

Kaiser M, Mose K and Alban L 2006. Which sows get shoulder ulcers? (in Danish) Danish Pig Production, Report 0620, 8pp.

Kaiser M, Bach-Mose K and Alban L 2007. Risk factors for shoulder ulcers in sows (in Danish). Dansk Veterinærtidsskrift 1, 20–26.

Kanis E, de Greef KH, Hiemstra A and van Arendonk JAM 2005. Breeding for societally important traits in pigs. Journal of Animal Science 83, 948–957.

Kass RE, Carlin BP, Gelman A and Neal RM 1998. Markov chain Monte Carlo in practice: a roundtable discussion. American Statistician 52, 93–100.

KilBride AL, Gillman CE and Green LE 2009. A cross sectional study of the prevalence, risk factors and population attributable fractions for limb and body lesions in lactating sows on commercial farms in England. BMC Veterinary Research 5, 30.

Knauer M, Stalder KJ, Karriker L, Baas TJ, Johnson C, Serenius T, Layman L and McKean JD 2007. A descriptive survey of lesions from cull sows harvested at two Midwestern U.S. facilities. Preventive Veterinary Medicine 82, 198–212.

Kranendonk G, Van der Mheen H, Fillerup M and Hopster H 2007. Social rank of pregnant sows affects their body weight gain and behavior and performance of the offspring. Journal of Animal Science 85, 420–429.

Le KM, Madsen BA and Barth PW 1984. An in-depth look at pressure ulcers using monolithic silicon pressure sensors. Plastic and Reconstructive Surgery 74, 745–753.

Lundgren H, Canario L, Grandinson K, Lundeheim N, Zumbach B, Vangen O and Rydhmer L 2010. Genetic analysis of reproductive performance in Landrace sows and its correlation to piglet growth. Livestock Science 128, 173–178.

McGlone JJ, Vines B, Rudine AC and Dubois P 2004. The physical size of gestating sows. Journal of Animal Science 82, 2421–2427.

Ministry of Food, Agriculture and Fisheries, Slotsholmsgade 12, DK-1260 Copenhagen V, Denmark (www.fvm.dk).

Misztal I, Tsuruta S, Strabel T, Auvray B, Druet T and Lee DH 2002. BLUPF90 and related programs (BGF90). Proceedings of the 7th World Congress on Genetics Applied to Livestock Production, August 19–23. Montpellier, France.

Mousing J, Noergaard N, kirkeskov Jensen M, Havbroe Andersen P, Lindahl J, Damm BI, Fraas Johnsen P, Hjelholt Jensen K, Gulisano CA, Auken J, Rosenberg Khawaja EO, Caspersen O, Feldstedt H and Groen Pedersen O 2008. Working group report on shoulder ulcers in sows (in Danish). 235pp. Retrieved November 20, 2010, from http://www.justitsministeriet.dk/fileadmin/downloads/Lovforberedende_udvalg/SR052008.pdf

Norsvin. P.O. Box 504, 2304 Hamar, Norway (www.norsvin.no).

Olesen I, Groen AF and Gjerde B 2000. Definition of animal breeding goals for sustainable production systems. Journal of Animal Science 78, 570–582.

Retsinformation.dk. Civilstyrelsen, Gyldenløvesgade 11, 2., DK-1600 Copenhagen V, Denmark (www.retsinformation.dk).

Rolandsdotter E, Westin R and Algers B 2009. Maximum lying bout duration affects the occurrence of shoulder lesions in sows. Acta Veterinaria Scandinavica 51, Article no. 44.

Sørensen G 2009. Thirty percent lower risk of decubital shoulder ulcers after increasing the number of daily feedings (in Danish). Report 847, Danish Pig Production, 13 pp.

Stalder KJ, Lacy RC, Cross TL and Conatser GE 2003. Financial impact of average parity of culled females in a breed-to-wean swine operation using replacement gilt net present value analysis. Journal of Swine Health and Production 11, 69–74.

Swedish Animal Health Service, Lindhagensgatan 126, Box 30167, 104 25 Stockholm, Sweden (www.svdhv.org).

Tsuruta S and Misztal I 2006. THRGIBBS1F90 for estimation of variance components with threshold-linear models. Proceedings of the 8th World Congress on Genetics Applied to Livestock Production, August 13–18, Belo Horizonte, MG, Brazil.

Valros A, Rundgren M, Spinka M, Saloniemi H, Rydhmer L, Hulten F, Uvnäs-Moberg K, Tomanek M, Krejci P and Algers B 2003. Metabolic state of the sow, nursing behaviour and milk production. Livestock Production Science 79, 155–167.

Whittemore CT 1996. Nutrition reproduction interactions in primiparous sows. Livestock Production Science 46, 65–83.

Zurbrigg K 2006. Sow shoulder lesions: risk factors and treatment effects on an Ontario farm. Journal of Animal Science 84, 2509–2514.