# Shoulder ulcers in sows are genetically correlated to leanness of young pigs and to litter weight

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Running head: Genetics of shoulder ulcers in sows

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## Abstract

The aim of this study was to estimate the heritability for shoulder ulcers (SU) and body condition (BCw) of sows at weaning, and the genetic correlations between these traits and some production and reproduction traits included in the current breeding goal of sow lines. The analyses were based on data on Swedish purebred Yorkshire from nucleus as well as multiplier herds. The estimated heritabilities were for BCw 0.21, and for SU 0.13. Significant genetic correlations were found between sidefat thickness (at 100 kg) and BCw (thicker fat layer at 100 kg – better condition at weaning), between sidefat thickness and SU (thicker fat layer – less SU), between litter weight at 3 weeks and BCw

(heavier litter – lower body condition), between litter weight at 3 weeks and SU (heavier litter – more SU). The genetic correlation between BCw and SU was also significant (lower body condition – more SU).

## Introduction

Shoulder ulcers in sows is a serious welfare issue (Broom, 1988). The establishment of ulcers is initiated by pressure when the sow is lying on the side, leading to compression of the blood vessels supplying skin and tissue around the shoulder blade. Decreased blood flow results in tissue damage and lesions (Jensen, 2009). The ulcers can vary from small patches to large and deep wounds.

According to a field study, approximately one third of Swedish commercial sows (Landrace*Yorkshire crosses) have signs of shoulder ulcers during lactation but there are large differences between herds (Ivarsson et al., 2009). Breed differences in the prevalence of shoulder ulcers have also been reported (Zurbrigg, 2006). Lundgren et al. (2012) have previously shown that shoulder ulcers have a genetic background in Norwegian Landrace. In that study, data on 5549 sows were analysed and 26% of the sows had signs of shoulder ulcers. The heritability for shoulder ulcers analysed as a threshold trait was estimated at 0.25 (posterior standard deviation 0.03). This indicates that the problem of shoulder ulcers should be a matter of concern in breeding programs, especially since there is a genetic correlation between shoulder ulcers and sow body condition at weaning (Hedebro Velander et al., 2011; Lundgren et al., 2012).

Selection for increased litter size and piglet growth has increased the demand on the sow to provide its piglets with enough milk. Four kg sow milk is needed for each kg piglet body weight gain (e.g. Noblet & Etienne, 1989). At the same time, breeding for leaner pigs may have limited the sows' ability to store body reserves for the energy demanding milk production. Lean sows and sows with large litters are less motivated to nurse the piglets than fat sows and sows with small litters (Wallenbeck et al., 2008). Even so, many sows become too thin during lactation (Sterning et al., 1990). Sows with a genetic capacity for high piglet growth loose more weight during lactation (Grandinson et al., 2005) and Lundgren et al. (2013) found an unfavourable genetic correlation between litter weight at 3 weeks and sow body condition at weaning. During lactation, the sow should balance the needs of its current litter and the ability to give birth to, and nurse, the next litter. A low body condition at first weaning is also correlated to the size of the second litter (Lundgren et al., 2013). This suggests that sows with high milk production are less fit for the following reproductive cycle.

A thinner fat layer increases the risk of  shoulder ulcers (Lundgren et al., 2012) and early culling (Whittemore, 1996). Shoulder ulcers may generate costs for treatments, reduced carcass value due to condemnation and high involuntary culling. For economic as well as ethical reasons, it is important with a production based on healthy sows that produce fast growing piglets and have a high longevity.

Our hypothesis is that sows with a genetic capacity to produce much milk (i.e. high litter weight at 3 weeks) have a large loss of body fat during lactation and thus an increased risk of developing shoulder ulcers during lactation as well as an increased risk of early culling. This could motivate an inclusion of shoulder ulcers or body condition at weaning in the genetic evaluation. With the long-term goal of improving sow and piglet welfare we have estimated the heritability for shoulder ulcers in sows and the genetic correlation between shoulder ulcers, body condition and some production and reproduction traits included in current breeding goal of sow lines.

## Material and methods

This study was based on data from the Swedish-Finnish breeding organisation Nordic Genetics, including records from both nucleus herds and multiplier herds with purebred Yorkshire sows (Table 1). Almost 100% AI is used in Swedish nucleus and multiplier herds, which ensures genetic ties between different herds. The prevalence and severity of shoulder ulcers (SU) in Yorkshire sows was in the period 2010 to 2012 recorded by herd staff at weaning in nucleus herds. The sows were scored from 0 (no sore) to 4 (severe open wounds), as described by Bonde et al. (2007). Body condition scores of the sows , also performed by herd staff, were recorded at weaning (BCw), on a scale from 0.5 (very thin) to 5 (very fat) with steps of 0.5 scores. The body condition scores were based on visual inspections and the farmers were instructed to put their hands on the sow to feel the thickness of the subcutaneous fat layer. The farms were provided by information from our group, on how to score these traits. The information included illustrations and photographs. However, no analyses of consistency/repeatability was performed. In total, data on SU for 4336 farrowings (2634 sows), and body condition scores for 4069 farrowings, was available for analysis. Among the records of SU, 38% were from parity 1, and  26%, 17% and 19% from parities 2, 3 and 4+.

Milk production of Swedish Yorkshire sows has since 2005 been indirectly measured by weighing all litters in first and second parity at three weeks of age (LW3). Litters from higher parities may also be weighed. The weighing was performed by the breeders when the piglets were between 18 and 24 days of age. Litter weight is regarded as a trait of the nursing sow and it includes both own piglets and cross fostered piglets. On average, litter size at 3 weeks of age was 10.1 piglets (SD=2.6). Approx. 18% of the weighed litters included fostered piglets. However, we have no information on the proportion of litters where piglets have been moved to other litters. Litter weight data were available for 17123 litters of 10903 sows (both purebred (77%) and crossbred [with Landrace boars] (23%) ). Litter size, recorded as number of liveborn piglets (LS) in the weighed litters was also included in the study. Within this breeding organisation, ‘number of liveborn piglets’ is defined as: number of pigs being alive, at first recording/counting after completed farrowing. According to this, piglets that had been born alive, but were crushed during the first hours after farrowing were not considered as liveborn.

Sows in nucleus herds are often culled already after first litter, in order to achieve a short generation interval. In the multiplier herds, sows are kept for several parities and data from multiplier herds are therefore of greater value, and less biased when studying longevity. Purebred sows in multiplier herds are in most cases born in nucleus herds, and have consequently tightly linked pedigree with the sows in nucleus herds. In this study, sow longevity was analysed as number of parities produced (STAY). Data from multiplier herds with Yorkshire sows were extracted in September 2013 and in order to give all sows enough time to have three litters; sows having their first litter later than June 2012 were excluded from the analyses. Data on 6555 sows born between 2004 and 2011 were included in the analysis.

In addition to the sow traits, two production traits from the field test performed in nucleus herds on all purebred pigs at approximately 100 kg were studied: age (days) at 100 kg (D100) and sidefat thickness measured with ultrasound (Sfat). Records from 64000 pigs, tested from 2009-2012 were included in the analyses.

*Statistical analyses*

Data editing as well as the phenotypic analyses were performed using the SAS software (ver. 9.2, SAS Inst. Inc., Cary, NC). The genetic analyses were performed using the DMU software (Madsen & Jensen, 2010). The scored traits SU and BCw, as well as STAY were transformed using Blom's method of computing normal scores (Blom, 1958) before the genetic analyses.

The statistical model for 'fattening traits' D100 and Sfat (pre-corrected to 100kg live weight) included the fixed effects of gender [G] and the combination of herd-birth year

[HYB]. The random effects were birth litter [L], batch-pen during fattening period [PEN], and the genetic effect of pig ([A]; animal effect).

(1) Y=G + HYB + L + PEN + A + error

The statistical model for 'litter related traits' LS, LW3, BCw and SU included the fixed effects of herd [H], farrowing year [Y], parity number ([PAR]; 1, 2, 3, 4+), and the random effects of herd-year-2month period ([HY2M]; when the sow farrowed), the permanent environmental effect of sow [PE], and the genetic effect of sow ([A];animal effect).

(2) Y= H + Y + PAR + HY2M + PE + A + error

For LS and LW3, the breed of boar (Landrace or Yorkshire) was also included as a fixed effect in the model, and for LW3, the model also included the regression on age at weighing.

The statistical model for STAY included the fixed effects of herd [H] and year for the sows first farrowing [Y1], and the random effect of sow ([A]; animal effect).

(3) Y=H + Y1 + A + error

Two multi-trait analyses with five trait combinations (LS, LW3, BCw, SU and STAY; D100, Sfat, BCw, SU and STAY) were performed. For variance components and parameters with two estimates, the mean of the estimates are presented together with the highest estimated standard error.

Environmental correlations between D100, Sfat and other traits and between STAY and other traits were set to 0 since the traits were recorded in different environments. All random effects were included in the phenotypic variance when calculating the heritability estimates. The pedigree file included 76709 animals.

## Results

The body condition scores at weaning (BCw) ranged from 0.5 to 5, with 3 being the most frequent score. Eight per cent of the sows had a higher body condition score at weaning as compared to farrowing, and 30 % had the same score at both registrations. Ninety per cent of the sows had no shoulder ulcers at weaning, whereas 7%, 2% and 1% had scores 1, 2 and 3+4. Shoulder ulcers in first parity was less common, as compared to later parities (6 vs 13 %). The average litter weight at three weeks of age (LW3) was 60.6 kg (Table 2).

Tables 1 and 2.

All variance estimates except the permanent environmental effect for LW3 were significantly larger than zero (Table 3). The heritability estimates for LS was the lowest (0.05) and the heritability estimates for LW3 and SU were also low, slightly above 0.1. The heritability estimates for BCw, STAY and D100 were higher, around 0.2 and the heritability estimate for Sfat was the highest, around 0.4.

Table 3

The genetic correlations between Sfat recorded on the young animal and BCw recorded at weaning was unfavourable and both Sfat and BCw were favourable correlated to SU (thicker fat layer – less shoulder ulcers). The genetic correlation between LW3 and BCw was high and negative (higher litter weight – lower body condition) and the correlation between LW3 and SU was unfavourable (higher litter weight – more shoulder ulcers). BCw was negatively correlated to STAY (higher body condition at weaning – lower longevity) but SU was not significantly correlated to STAY (Table 4). The estimates of the three genetic correlations that were estimated twice, were quite consistent: BCw and SU (-0.41 and -0.37); BCw and STAY (-0.34 and -0.23); SU and STAY (0.04 and -0.03).

Table 4

## Discussion

Heritability estimates

Shoulder ulcers is a heritable trait. The heritability was estimated at 0.13 based on Swedish Yorkshire sows in this study and at 0.25 (on the underlying scale) based on Norwegian Landrace sows by Lundgren et al. (2011). The frequency of shoulder ulcers differed between these populations, 10 vs 26 %, although the same method and scale was used for registration. According to Zurbrigg (2006), Canadian Landrace sows had a 3 times higher risk of developing shoulder ulcers than Canadian Yorkshire sows. Hedebro Velander et al. (2011) reported a heritability of 0.18 for ‘incidence of ulcers’ in cross-bred sows. Also, in this study body condition score at weaning was recorded in a similar way as in Lundgren et al. (2011), resulting in similar heritability estimates (0.21 and 0.14). Thus, estimates of SU and BC presented are all high enough to indicate the possibilities to improve them by selection.

Sows should have at least three litters to return their rearing costs (Stalder et al., 2003) but according to the data used in this study only 63% of the sows in multiplier herds had at least three litters. Thus, one third or these sows did not positively contribute to the economy of the herd. The heritability for STAY was estimated at 0.17 which is higher than the heritability for stayability previously estimated by Engblom et al. (2009) on crossbred sows in commercial herds ($h^2 = 0.06$). Major differences between these two studies are: purebred vs crossbred sows; last parity number vs. days between first farrowing and culling; analysed as linear measurement vs. survival analyses. All this might have influenced the difference between the heritability estimates.

Genetic correlations

Our hypothesis that sows with a genetic capacity to produce much milk (i.e. high litter weight at 3 weeks) have a large loss of body fat during lactation and an increased risk of developing shoulder ulcers during lactation was verified by our estimated genetic correlation. However, we found no significant genetic correlations between STAY and LW3 or SU. Our hypothesis was that shoulder ulcers are genetically correlated to sow longevity. This hypothesis was not verified since the genetic correlation between SU and STAY was close to zero and insignificant. This indicates that selection against SU would not result in a correlated improved stayability. However, between BCw and STAY the correlation was significant (thinner sows at weaning →higher stayability). The biological background for this is unclear to us. No phenotypic correlation between SU and STAY was estimated in this study since SU was recorded in nucleus herds and STAY in multiplier herds. Rodríguez et al. (2011) found, on the basis of field data from 34 commercial Danish herds, that shoulder ulcers and body condition score had significant effects on involuntary culling. Engblom et al. (2007) studied culling of sows in Swedish commercial herds. Shoulder ulcers, abscesses, no appetite and ‘general bad condition’ all together where recorded as removal cause for only 3.1 per cent of the removed sows. Differences (Denmark vs Sweden) in genetic material, feeding and management might be the cause of these differences in associations in these two studies.

Significant unfavourable genetic correlations were found between Sfat recorded on young pigs at 100 kg and SU, and between LW3 and SU. This is alarming since both leanness and sows’ ability to make the piglets grow are common selection traits in dam lines. We are not aware of any previous estimate of the correlation between leanness of young animals and SU. Lundgren et al. (2011) estimated the genetic correlation between shoulder ulcers and mean piglet weight at 3 weeks at 0.23 which is in accordance with present study. In contrast to the unfavourable correlation between LW3 and SU, the genetic correlation between LS and SU was not significant. Litter size is part of litter weight, but piglet mortality and cross fostering weakens the relationship between litter size at birth and number of piglets nursed by the sow. It is also possible that the farmers use cross fostering to compensate for certain sows’ predisposition for shoulder ulcers.

The genetic correlation between Sfat and BCw was positive. The young, unmated gilt at 100 kg is in a very different physiological phase compared to the lactating sow. Even so, the thickness of the body fat layer seems to be governed by partly the same genes during both phases, and both Sfat and BCw are correlated with SU. The high and unfavourable genetic correlation between LW3 and BCw in this study is in accordance with the correlation between these traits estimated at -0.54 by Lundgren et al. (2013) in a Landrace population.

There is a significant genetic correlation between SU and BCw; $r_g$ = -0.39 in this study and -0.59 in the study by Lundgren et al. (2011). The way this scoring was performed might give bias to the correlation estimated between SU and BCw.  These two scorings were performed at the same occasion, by the same herd staff, and there might be a risk that, within sow, one finding would influence the second score. There are also several phenotypic studies showing that lean sows have an increased risk of getting shoulder ulcers (Davies et al., 1997; Bonde et al., 2004; Zurbrigg, 2006; Knauer et al., 2007; Ivarsson et al., 2009). Thus, apart from the negative effects of low body condition on sow reproduction stressed by Eissen et al. (2003), Thaker & Bilkei (2005) and Lundgren (2011) among others, the risk of shoulder ulcers is an additional reason for keeping sows in good condition throughout lactation.

Breeding goal

The goal conflict between high milk production and piglet welfare on one hand and high body condition and sow welfare on the other hand should not be ignored; the possibility to include SU or BCw in the genetic evaluation of dam lines should be considered. It is, however, difficult to calculate the right economic weight for these traits which have both market values (related to e.g. feed costs and costs for medical treatments) and non-market values related to animal welfare. An alternative approach could be to aim for no further deterioration in SU or BCw when deciding the economic weights.

If shoulder ulcers is not genetically correlated to sow longevity, as indicated by our results, possible motives for including less shoulder ulcers in the breeding goal are to be found in the animal welfare concern. We are not aware of any scientific study describing how painful shoulder ulcers are, but Herskin et al. (2011) wrote that “On the basis of the tissue that is involved, we assume that the development and presence of decubital shoulder ulcers are a painful and prolonged condition”. Furthermore, each shoulder sore is a potential entrance for microbes. Karlsson et al. (2013) found Treponema spp. in shoulder ulcers and they suggest a possible infection route, through biting and licking, from piglets’ mouth to sows’ shoulder ulcers.

Since recording of sow body condition is already performed by farmers when determining individual feeding levels for sows, the introduction of BCw as a new selection trait might be easier than the introduction of SU. The higher heritability of BCw than of SU found in this study is another reason to choose BCw as a selection trait. In Norwegian Landrace, the heritability estimate was however higher for SU than for BCw (Lundgren et al., 2011). As for any other traits, genetic parameters for SU must of course be estimated for each breed and production system. The desired genetic change in shoulder ulcers and sow body condition should also be discussed and decided upon for each sow line. In the breeding program for Norwegian Landrace, both shoulder ulcers and body condition at weaning are included in the genetic evaluation, with an economic weight of 1 and 4 per cent of the total breeding value (Norsvin, 2013). Inclusion of these traits may reduce the economic return in a short-term perspective, due to a lower progress in production traits. Such a discussion will (as described by Kanis et al., 2005) include questions of to what extent, how fast and at what expense traits important for welfare should be genetically improved. These are difficult questions, but due to the prevalence of shoulder ulcers and the unfavourable genetic correlations between traits important for pig production and shoulder ulcers, they cannot be neglected.

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Table 1. Traits studied and their abbreviations, type and number of herds where the traits were recorded and first and last year of recording data for the analyses

| Trait | Abbrevi-ation | Recording herds | Recording period |
|---|---|---|---|
| Days to 100 kg | D100 | 13 nucleus | 2009-2012 |
| Sidefat at 100 kg | Sfat | 13 nucleus | 2009-2012 |
| No. piglets born alive | LS | 15 nucleus | 2005-2012 |
| Litter weight at 3 wks | LW3 | 15 nucleus | 2005-2012 |
| Body condition score[1] | BCw | 15 nucleus | 2010-2012 |
| Shoulder ulcer score[2] | SU | 15 nucleus | 2010-2012 |
| Stayability[3] | STAY | 18 multiplier | 2004-2013 |

[1] Body condition was scored at weaning from 0.5 (very thin) to 5 (very fat)
[2] Shoulder ulcer was scored at weaning from 1 (no sore) to 4 (severe open wounds)
[3] Sow stayability (longevity): highest parity number of purebred Yorkshire sows in multiplier herds

Table 2. Number of observations, mean, median, minimum and maximum values for the studied traits[1]

| Trait | Trait unit | No. of obs. | Mean | Stand. dev. | Min | Max |
|---|---|---|---|---|---|---|
| D100 | day | 63236 | 156.7 | 17.5 | 110 | 220 |
| Sfat | mm | 63298 | 10.1 | 1.9 | 1.9 | 23.7 |
| LS | piglet | 17123 | 11.8 | 3.2 | 0 | 23 |
| LW3 | kg | 17123 | 60.6 | 14.4 | 7 | 130 |
| BCw[2] | score | 4069 | 2.4 | | 0.5 | 5 |
| SU[3] | score | 4336 | 0.14 | | 0 | 4 |
| STAY[4] | parity no. | 6555 | 3.20 | | 1 | 13 |

[1] See Table 1 for trait abbreviations
[2] Body condition was scored from 0.5 (very thin) to 5 (very fat)
[3] Shoulder ulcer was scored from 0 (no sore) to 4 (severe open wounds)
[4] Sow stayability (longevity): highest parity number of purebred Yorkshire sows in multiplier herds

Table 3. Estimated variance components[1] for pen ($\sigma^2_{pen}$), litter ($\sigma^2_{l}$), herd-year-2month ($\sigma^2_{HY2M}$), permanent environmental ($\sigma^2_{pe}$), additive genetic ($\sigma^2_{a}$) and error effects ($\sigma^2_{e}$) with standard errors[1] as subscripts and heritabilities ($h^2$)

| Trait[2] | $\sigma^2_{pen}$ | $\sigma^2_{l}$ | $\sigma^2_{HY2M}$ | $\sigma^2_{pe}$ | $\sigma^2_{a}$ | $\sigma^2_{e}$ | $h^2$ |
|---|---|---|---|---|---|---|---|
| D100 | $47.94_{1.07}$ | $18.32_{0.72}$ | - | - | $34.01_{2.36}$ | $79.38_{1.32}$ | 0.19 |
| Sfat | $0.33_{0.01}$ | $0.29_{0.01}$ | - | - | $1.21_{0.05}$ | $1.37_{0.03}$ | 0.38 |
| LS | - | - | $0.12_{0.03}$ | $0.46_{0.12}$ | $0.50_{0.09}$ | $8.35_{0.14}$ | 0.05 |
| LW3 | - | - | $11.76_{1.06}$ | $0.74_{2.14}$ | $19.99_{2.07}$ | $136.91_{2.24}$ | 0.12 |
| BCw | - | - | $0.08_{0.02}$ | $0.10_{0.02}$ | $0.18_{0.03}$ | $0.53_{0.02}$ | 0.21 |
| SU | - | - | $0.01_{0.00}$ | $0.04_{0.01}$ | $0.04_{0.01}$ | $0.22_{0.01}$ | 0.13 |
| STAY | - | - | - | - | $0.15_{0.02}$ | $0.73_{0.02}$ | 0.17 |

[1] For variance components and parameters with two estimates, the mean of the estimates are presented together with the highest estimated standard error.
[2] See Table 1 for trait abbreviations

Table 4. Genetic (above diagonal) and environmental (below diagonal) correlations[1] between traits, with standard error as subscripts[2]

| Trait[2] | LS | LW3 | BCw | SU | STAY[3] |
|---|---|---|---|---|---|
| D100[3] | | | $-0.25_{0.07}$ | $-0.01_{0.09}$ | $0.33_{0.09}$ |
| Sfat[3] | | | $0.35_{0.06}$ | $-0.29_{0.08}$ | $0.19_{0.07}$ |
| LS | | $0.02_{0.10}$ | $0.00_{0.13}$ | $-0.06_{0.16}$ | $0.56_{0.11}$ |
| LW3 | $0.24_{0.01}$ | | $-0.65_{0.08}$ | $0.35_{0.12}$ | $0.15_{0.10}$ |
| BCw | $-0.11_{0.03}$ | $-0.24_{0.03}$ | | $-0.39_{0.12}$ | $-0.28_{0.13}$ |
| SU | $-0.02_{0.03}$ | $0.03_{0.03}$ | $-0.14_{0.02}$ | | $0.01_{0.16}$ |

[1] For variance components and parameters with two estimates, the mean of the estimates are presented together with the highest estimated standard error.
[2] See Table 1 for trait abbreviations
[3] Environmental correlations between D100, Sfat and other traits and between STAY and other traits were set to 0.