animal

Heritabilities of osteochondral lesions and genetic correlations with production and exterior traits in station-tested pigs

H. Luther[†], D. Schwörer and A. Hofer

SUISAG, Allmend, 6204 Sempach, Switzerland

Osteochondrosis might reduce the performance of slaughter pigs, longevity of sows and animal welfare. The aim of the present work was to describe the prevalence in Swiss breeds and to analyse the genetic background of osteochondral lesions. Between January 2002 and December 2005, about 9500 station-tested pigs were examined for several exterior traits before slaughtering at the Swiss pig performance testing station using the Swiss linear description system with a scale from 1 to 7 per trait. The animals belonged to three breeds: Large White dam line, Swiss Landrace and Large White sire line. Additionally, a random sample of these pigs (n = 2622) was examined for osteochondral lesions at seven positions of the carcass after dissection. At first, the surface and shape of the femur, humerus, radius and ulna at the joints were evaluated by a trained person. Afterwards these bones were sawed and the state of the cartilage and the distal epiphyseal cartilage of the ulna was examined at the cutting surface. Osteochondral lesions were scored on a scale from 1 to 6. The prevalence of osteochondral lesions was low at head of humerus, condylus lateralis humeri, radius and ulna proximal and head of femur. Osteochondral lesions at condylus medialis humeri (CMH), distal epiphyseal cartilage of ulna (DEU) and condylus lateralis femoris (CMF) exhibited phenotypic and genetic variance. Their heritabilities ranged from 0.16 to 0.18 using linear mixed animal models. Therefore, it is possible to reduce the prevalence of osteochondral lesions by selection in principle. Exterior traits showed low heritabilities (0.10 to 0.26) but several favourable genetic correlations with osteochondral lesions at CMH, DEU and CMF with low to moderate magnitude. Genetic correlations between osteochondral lesions and production traits were low.

Keywords: genetic correlation, heritability, osteochondritis, pigs

Introduction

Osteochondrosis (OC) is a disturbance of the enchondral ossification in the joint cartilage and in the growth plates (Olsson and Reiland, 1978). Osteochondral lesions may cause or aggravate leg weakness (Lundeheim, 1987; Jørgensen, 2000), reduce longevity of sows and boars and may be painful, if considerable OC lesions occur. Therefore, concerning economic and animal welfare aspects, OC is of noticeable relevance.

It is well known that besides environmental factors genetic effects influence the occurrence of OC lesions (Lundeheim, 1987; Jørgensen and Andersen, 2000; Kadarmideen *et al.*, 2004). The authors estimated low-to-moderate heritabilities for the occurrence of osteochondral lesions and found differences between breeds. But the examination methods, the included cartilages and the prevalence of osteochondral lesions differ between their studies.

Direct selection against osteochondral lesions would be very difficult, because only dissected or X-rayed animals could provide information. Thus, including other genetically related traits − e.g. exterior characteristics − in pig breeding programmes may be a preferable way to control the genetic aspects of OC. Therefore, genetic parameters of these related traits, like heritabilities and genetic correlations, are needed. Lundeheim and Rydhmer (1990), Jørgensen and Andersen (2000) and Kadarmideen *et al.* (2004) estimated genetic correlations between OC and production traits. They found only few unfavourable associations with moderate magnitude. Some authors (Jørgensen *et al.*, 1995; Jørgensen, 2000) found slight phenotypic associations between OC and several leg weakness symptoms. But to our knowledge, only Jørgensen and Andersen (2000) estimated genetic correlations between exterior traits and OC. They found some favourable, moderate genetic associations.

The aim of the present study is to describe the prevalence of osteochondral lesions at different positions of the carcass in Swiss breeds based on station-tested pigs, which were
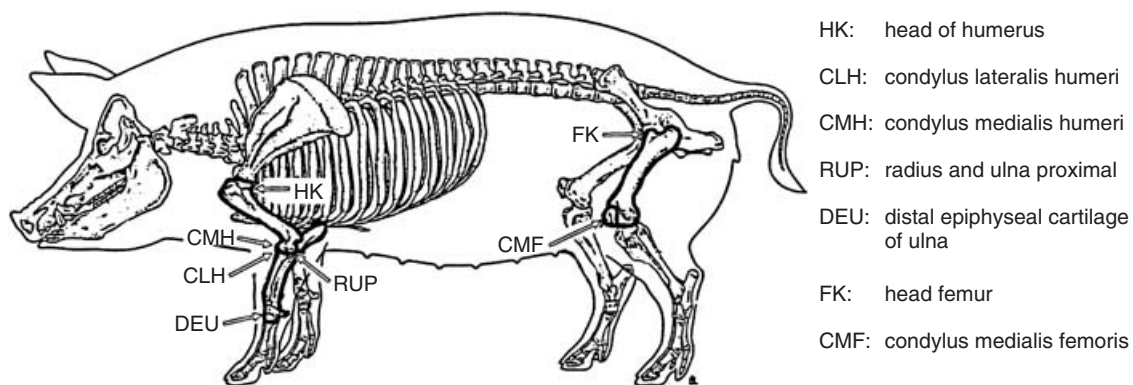

[†] hlu@suisag.ch

1105

Figure 1 Examinations of osteochondral lesions at the Swiss test station (Schwörer *et al.*, 1985).

born at several Swiss breeding farms. Secondly, heritabilities of osteochondral lesions and their genetic correlations with some production and several exterior traits will be estimated.

Material and methods

Station-test

In Switzerland, approximately 3000 growing pigs are performance tested per year. Purebred animals of the Large White dam line (LW_{DL}), Swiss Landrace (SLR) and Large White Sire line (LW_{SL}) make up more than 80% of all test animals. Usually, a test group consists of two full-sibs (one female and one male castrate). Animals are housed in 12 barns, each with eight pens and about 10 animals of both sexes per pen. Electronic feed dispensers are used to feed the animals *ad libitum*. Two different diets are used during the test. At first, each pig obtains approximately 80 kg of a starter feed (19% CP, 13.3 MJ digestible energy (DE), 10 g/kg lysine, 8 g/kg Ca, 5 g/kg P). Afterwards, a finisher feed (15% CP, 12.7 MJ DE, 9 g/kg lysine, 8 g/kg Ca, 5 g/kg P) is used. The test starts at 30 kg live weight and ends with approximately 103 kg. Every week, 40 to 70 animals are slaughtered in a small abattoir at the test station and the left half of the carcass is dissected.

Average daily gain (ADG) from 30 to 103 kg describes the growth of animals. Percentage of premium cuts (PPC) specifies the leanness of carcasses. PPC is defined as the weight of ham, loin and shoulder without fat layer proportional to carcass weight. A full description of the Swiss station-test is given in the annual report of SUISAG (2006).

Examination of bones

Osteochondral lesions were already observed at the Swiss test station in the 1980s and early 1990s (Schwörer *et al.*, 1991). In 2002, more weight was placed on daily gain in the overall breeding goal. SUISAG decided to monitor the occurrence of osteochondral lesions, because unfavourable genetic correlations with daily gain may exist.

Since 2002, osteochondral lesions have been examined at the following bones and joints: head of humerus (HK),

condylus medialis humeri (CMH), condylus lateralis humeri (CLH), radius and ulna proximal (RUP), head of femur (FK), distal epiphyseal cartilage of ulna (DEU) and condylus medialis femoris (CMF). Figure 1 shows the corresponding positions at the carcass. At first, a trained person examines the surface and shape of these bones at the joints. Afterwards each bone is sawed with a band saw and the state and shape of the cartilage and the DEU is examined at the cutting surface. Scores from 1 to 4 are used to record the extent of the osteochondral lesion. A score of 1 denotes 'no visible osteochondral lesion'. Scores 2 to 4 denote 'mildly to severely affected', respectively. Osteochondral lesions at the DEU and CMF are scored from 1 to 6, because these lesions seemed to be more variable. More details concerning the Swiss examination of osteochondral lesions are given by Schwörer *et al.* (1985).

Linear description of exterior

A linear description system (LD) has been used to evaluate exterior characteristics of Swiss gilts and boars (on-farm test) and all station-tested pigs since 2000. Five traits are used to describe the rear and fore extremities: X-O posture at rear legs (XORL), side-view angle of rear legs (SVARL), angle of pasterns at rear legs (APRL), size of the inner claw in comparison to the outer claw at rear legs (SICRL) and side-view angle of fore legs (SVAFL). These five traits are scored from 1 to 7 with score 4 as the optimal phenotype and scores 3 to 1 and 5 to 7 as more and more extreme and therefore negative phenotypes. Scores from 4 to 7 are used to describe the regularity at the loin (LOIN). Score 4 denotes 'regular' and scores 5 to 7 denote that the animals are increasingly narrow at the loin in comparison to the whole body. Finally, scores from 4 to 7 are used to evaluate the locomotion (LOC) of the animal. Score 4 denotes 'regular locomotion' and scores 5 to 7 denote a more and more lurching or stiff locomotion. Figure 2 shows a scheme of the linear description system. Tarrés *et al.* (2006) recently showed that gilts with an optimum exterior – i.e. only scores of 4 at the linear description – stayed longer in the farms compared with gilts with a suboptimal exterior.

The present study includes exterior examinations of station-tested animals, which were performed approximately

Figure 2 Scheme of the Swiss linear description system (without teat description) (some drawings from Van Steenbergen, 1990).

4 weeks to 1 week before slaughtering. Seven trained persons described the animals during the evaluation period. The length of the carcass (CL) of every animal was measured from the pubis bone to the cervical vertebra after slaughtering. A detailed report of the applied linear description system and the genetic evaluation of exterior traits in Switzerland is given by Hofer (2004).

Data

This study includes 9511 performance-tested animals of the purebred lines LW_{DL}, SLR and LW_{SL} that were slaughtered between January 2002 and December 2005 (Table 1). Table 2 presents the average fattening and carcass performance of the station-tested animals. The test animals are progeny of 1051 sires and 19 988 animals are included in the pedigree file.

About 27% of all slaughtered animals were examined for osteochondral lesions ($n = 2622$; Table 3). The number of observations was slightly reduced at RUP and DEU, because these bones were used for another project. Data from linear description were available for nearly all animals. Approximately 50 test animals had no or incomplete exterior data due to different reasons (e.g. clinical lameness at description day, etc.).

Statistical analysis

Genetic parameters were estimated with univariate and multivariate linear mixed animal models using VCE5 (Kovač *et al.*, 2002). Due to the categorical characteristic and the

Table 1 *Distribution of station-tested pigs*

Breed[†]	Female	Castrate	Total
LW_{DL}	2862	3339	6201
SLR	830	934	1764
LW_{SL}	852	694	1546
Total	4544	4967	9511

[†]LW_{DL} = Large White dam line; SLR = Swiss Landrace; LW_{SL} = Large White sire line.

Table 2 *Mean and distribution of performance traits (n = 9511)*

Trait[†]	Mean	s.d.	Min	Max
LW (kg)	103.33	3.51	85.50	118.60
ADG (g/day)	865.38	94.10	544.60	1218.00
FCR (kg/kg)	2.58	0.21	1.99	3.58
FI (kg/day)	2.23	0.24	1.45	3.21
CL (cm)	96.95	2.82	85.00	110.00
PPC (%)	57.66	2.54	46.98	65.90

[†]LW = live weight at slaughtering; ADG = average daily gain (30 to 103 kg); FCR = feed conversion ratio; FI = average daily feed intake; CL = length of carcass; PPC = percentage of premium cuts.

very skewed distribution, HK, CLH, RUP and FK were excluded from the final statistical analyse. Preliminary univariate estimations showed nearly no genetic variance for these four traits. CMH, DEU and CMF exhibited a prevalence of more than 10% and remained in the

1107

statistical analyses with linear models. The heritabilities on the underlying liability scale might be underestimated according to the formula of Robertson and Lerner (1949) due to the use of linear models, especially for CMH. But according to Gianola (1984) the genetic correlations with other continuously distributed traits are almost not affected. Estimations of heritabilities and genetic correlations of the 13 traits were performed in 14 separate runs. It was not possible to run more than seven traits simultaneously. The results of all runs were averaged. Slightly different linear mixed models were used for different traits.

ADG:

$$y_{himnop} = \mu + BREED_h + BARN\_PER_i + SEX_m$$
$$+ farm\_y_n + litter_o + animal_p + e_{himnop}$$

PPC, CL:

$$y_{hjmnop} = \mu + BREED_h + SL\_DAY_j + SEX_m + b_m LW$$
$$+ farm\_y_n + litter_o + animal_p + e_{hjmnop}$$

XORL, SVARL, APRL, SICRL, SVAFL, LOIN, LOC:

$$y_{hilmnop} = \mu + BREED_h + BARN\_PER_i + LD\_PE_l + SEX_m$$
$$+ farm\_y_n + litter_o + animal_p + e_{hilmnop}$$

CMH, DEU, CMF:

$$y_{hkmnop} = \mu + BREED_h + SL\_PER_k + SEX_m + b_m LW$$
$$+ farm\_y_n + litter_o + animal_p + e_{hkmnop}$$

with:

y	observation of test animal p ($p = 1, 2, \ldots, 9511$)
μ	overall mean
$BREED_h$	fixed effect of breed ($h = LW_{DL}$, SLR, LW_{SL})
$BARN\_PER_i$	fixed effect of barn × period combination ($i = 1, 2, \ldots, 149$)
SL_DAY_j	the fixed effect of slaughter day ($j = 1, 2, \ldots, 213$)
SL_PER_k	fixed effect of slaughter period ($k = 1, 2, \ldots, 8$)
LD_PE_l	fixed effect of the person performing the LD ($l = 1, 2, \ldots, 7$)
SEX_m	fixed effect of sex ($m = $ female, castrate)
$b_m LW$	partial linear regression on live weight within sex
$farm\_y_n$	random effect of farm of origin × year ($n = 1, 2, \ldots, 249$)
$litter_o$	random effect of the litter ($o = 1, 2, \ldots, 4763$)
$animal_p$	random effect of the animal ($p = 1, 2, \ldots, 9511$)
e	random error of test animal p ($p = 1, 2, \ldots, 9511$).

Table 3 *Distribution of osteochondral lesions within breeds[†]*

Score	HK	CMH	CLH	RUP	DEU	FK	CMF
Large White dam line							
1	1725	1554	1722	1600	235	1744	1266
2	16	156	24	113	677	3	460
3	7	38	2	1	477	1	20
4	0	0	0	0	253	0	2
5					72		0
6					0		0
Total	1748	1748	1748	1714	1714	1748	1748
Swiss Landrace							
1	408	378	399	391	58	411	240
2	4	29	12	12	157	1	157
3	0	5	1	0	117	0	14
4	0	0	0	0	50	0	1
5					19		0
6					2		0
Total	412	412	412	403	403	412	412
Large White sire line							
1	456	407	456	410	42	462	366
2	5	46	3	36	157	0	92
3	1	9	3	0	130	0	3
4	0	0	0	0	87	0	1
5					31		0
6					0		0
Total	462	462	462	446	447	462	462

[†]For abbreviations see Figure 1.

Table 4 *Significance of fixed effects[†]*

	BREED	SEX	SL_PER	LW
CMH	n.s.	***	n.s.	n.s.
DEU	***	n.s.	***	***
CMF	***	***	***	n.s.

[†]For abbreviations see Figure 1 and the text. ***$P \leqslant 0.001$.

All test animals that were fattened in the same barn and period were used as a contemporary group for ADG and exterior traits. Eight slaughter periods (6 months) were used as a contemporary group for osteochondral lesions traits, because only approximately 10 to 15 pigs were examined for OC lesions at each week after slaughtering. The test animals were born at 78 farms within 4 years and belong to 4763 different litters. ADG values were pre-corrected to a constant live weight at slaughtering (103 kg). Therefore, no regression on live weight was included in the model concerning this trait. No correction for live weight was possible for exterior traits, because pigs were not weighed at the description day.

The statistical software S-PLUS (S-PLUS, 1999) was used to test the significance of fixed effects for osteochondral lesions (Table 4).

Results and discussion

The occurrence of osteochondral lesions varied at different positions of the carcass (Table 3). Very few animals showed osteochondral lesions at HK, CLH and FK. Only approximately 6% of all pigs exhibited mildly osteochondral lesions at RUP. Substantial phenotypic variation was observed at CMH, CMF and especially at DEU.

The distribution of osteochondral lesions in the present study is in good agreement with Kadarmideen *et al.* (2004). Those authors used a sub-data set of this study that included only test animals slaughtered in 2002 and 2003. Jørgensen *et al.* (1995) observed a higher prevalence and variation of subchondral lesions at the medial humeral and femoral condyles in Danish Landrace boars. The prevalence at the lateral humeral condyles was similar to the present study and osteochondral lesions at the distal ulna growth plate showed the most phenotypic variation also. The differences might be caused by different definitions of osteochondral lesion scores, different sexes of the animals and differences between the Swiss and Danish environments and populations. Jørgensen and Andersen (2000) X-rayed Danish Yorkshire and Landrace boars. They observed a slightly higher prevalence of OC at the humeral condyles and an explicitly higher prevalence at the femoral condyles. Concerning the distal ulna growth line OC scores varied conspicuously in Danish Landrace boars. But 67% of the Yorkshire boars showed no OC at this growth plate. So, variation was reduced in the Yorkshire breed.

Differences between breeds were moderate and inconsistent at different positions of the carcass in the present study (Table 3). SLR showed proportionally more osteochondral lesions at CMF but slightly less at RUP compared with Large White dam and sire line. In contrast, Jørgensen and Andersen (2000) reported that Danish Landrace boars were significantly more severely affected than Yorkshire boars regarding OC in all localities except of the anconeal process. Differences between Swiss and Danish populations might be a major reason for this disagreement.

Jørgensen (1995) found no significant differences between sexes concerning OC, which is in good agreement with DEU in the present study (Table 4). Otherwise, castrates were significantly more affected at CMH and CMF than females in our study.

Conspicuous phenotypic variation was observed in all linearly described exterior characteristics (Table 5). The scores of XORL showed almost a Gaussian distribution with an average of 3.46. Because 4.0 is the desired average for XORL, it is necessary to reduce the X posture of the rear legs in the Swiss population. Approximately 77% of all animals exhibited an optimal SVARL. But it is still necessary to reduce the proportion of animals with a 'standing under position' (score 3). On average, the population is very close to the optimum score of 4 concerning the angle of pasterns but a lot of animals showed slightly too weak (score 3) or slightly too steep (score 5) pasterns. Most of the animals had a smaller inner claw compared with the outside claw.

Table 5 *Distribution of the scores of linear description[†]*

Score	XORL	SVARL	APRL	SCIRL	SVAFL	LOIN	LOC
1	6	2	31	265	27		
2	389	106	350	2170	159		
3	4704	1799	1668	5989	647		
4	4003	7301	5795	1027	6571	2655	5647
5	328	253	1429	11	1906	5721	3470
6	30	0	187	0	147	1079	332
7	1	0	1	0	4	7	11
Total	9461	9461	9461	9462	9461	9462	9460
Mean	3.46	3.81	3.93	2.83	4.12	4.83	4.44

[†]For abbreviations see Figure 2.

Table 6 *Variance components and heritabilities (h^2) of osteochondral lesions at different positions of the carcass (univariate estimation)[†]*

	Variance components							
	Phenotypic	Farm_y	Litter	Genetic	Error	c^2	h^2	s.e.
CMH	0.1514	0.0000	0.0102	0.0242	0.1170	0.07	0.16	0.04
DEU	0.9563	0.0120	0.0119	0.1721	0.7602	0.01	0.18	0.03
CMF	0.2371	0.0070	0.0000	0.0418	0.1883	0.00	0.18	0.03

[†]c^2 = ratio of litter variance, s.e. = standard error of h^2 and for other abbreviations see Figure 1.

Approximately 70% of all animals showed an optimal angle of the fore legs and the average score is close to the optimum. Nearly 60% of all pigs showed a fully regular locomotion and approximately 4% exhibited conspicuous problems (score 6 or 7) concerning locomotion.

Serenius *et al.* (2001) analysed exterior data of Finnish progeny and performance tests. Approximately 50% of Finnish Landrace and Large White pigs exhibited small inner claws. Jørgensen (2000) examined 117 Danish crossbred and Yorkshire gilts at 6 months of age for leg weakness symptoms. A high proportion of Danish gilts showed uneven claws especially in crossbred sows. Thus, smaller inner claws seem to be common in different pig populations and pig breeding programmes should aim at equalising the size of both claws in the future.

Approximately 55% of the 117 Danish gilts (Jørgensen, 2000) exhibited a posture of rear legs called 'turned out', which is synonym to the Swiss 'X posture' and in prevalence very close to our results. About 15% of the Danish gilts showed too weak pasterns and approximately 20% too steep pasterns, which is in good agreement to our findings. In contrast, Jørgensen and Andersen (2000) observed only approximately 5% weak pasterns but about 80% too steep pasterns in Danish Landrace and Yorkshire boars. Most of the Danish gilts showed a normal locomotion (Jørgensen, 2000). But approximately 25% exhibited a more or less stiff gait at the rear legs. In contrast, most of the Danish boars showed a stiff locomotion (Jørgensen and Andersen, 2000). The Danish results suggest that the occurrence of leg weakness symptoms is different between sows and boars

Table 7 *Heritabilities (diagonal, bold), phenotypic correlations (above diagonal) and genetic correlations (below diagonal) of multivariate analyses[†]*

	ADG	PPC	XORL	SVARL	APRL	SICRL	SVAFL	LOC	CL	LOIN	CMH	DEU	CMF
ADG	**0.27**	−0.25	0.04	0.01	0.00	−0.03	−0.01	0.04	−0.12	0.00	−0.01	0.00	0.09
PPC	−0.07	**0.62**	−0.03	0.00	0.07	−0.01	0.07	0.02	0.17	0.24	−0.02	0.03	−0.03
XORL	0.08	0.02	**0.13**	−0.02	−0.19	−0.01	−0.10	−0.12	−0.12	−0.02	−0.02	0.02	0.01
SVARL	−0.09	−0.06	−0.05	**0.10**	0.14	0.07	−0.01	−0.20	−0.03	−0.12	−0.03	0.02	−0.06
APRL	−0.12	0.09	−0.45	0.40	**0.26**	0.02	0.14	0.02	0.02	0.01	0.02	−0.04	−0.01
SICRL	0.00	−0.08	−0.17	0.18	0.08	**0.15**	−0.04	−0.11	−0.06	−0.05	−0.03	−0.01	−0.08
SVAFL	−0.07	0.13	−0.45	0.07	0.40	−0.04	**0.14**	0.11	0.13	0.02	−0.03	0.02	0.02
LOC	0.30	−0.05	−0.12	−0.57	0.03	−0.29	0.20	**0.14**	0.04	0.13	0.01	−0.01	0.03
CL	−0.10	0.17	−0.25	−0.17	−0.09	−0.06	0.28	−0.06	**0.61**	0.01	−0.03	−0.03	0.02
LOIN	0.16	0.50	0.08	−0.28	0.12	−0.14	0.00	0.41	0.03	**0.20**	0.00	0.00	0.00
CMH	−0.11	0.06	<u>−0.17</u>	<u>−0.27</u>	−0.04	<u>−0.16</u>	−0.01	<u>0.16</u>	−0.07	*−0.20*	**0.17**	0.01	0.06
DEU	0.01	0.06	0.01	<u>−0.15</u>	−0.11	<u>−0.20</u>	−0.09	<u>0.54</u>	−0.07	<u>0.18</u>	0.13	**0.17**	0.01
CMF	*0.21*	0.11	0.11	<u>−0.14</u>	−0.12	<u>−0.25</u>	−0.03	<u>0.27</u>	0.12	<u>0.20</u>	−0.14	−0.10	**0.17**

[†]For abbreviations see Figures 1 and 2 and Table 2. Underlined values indicate notable genetic correlation is favourable ($r_g \geqslant \pm 0.15$). Italic values indicate notable genetic correlation is unfavourable ($r_g \geqslant \pm 0.15$).

especially for pasterns and locomotion. In the present study we did not find differences between females and castrates concerning exterior traits.

Heritabilities and correlations

At first, univariate analyses were performed to estimate the variance components of osteochondral lesion at CMH, DEU and CMF (Table 6). The additive genetic effect explains a noticeable proportion of the total phenotypic variance of osteochondral lesions. Hence, heritabilites for these traits ranged from $h^2 = 0.16$ to 0.18. The corresponding standard errors were low.

The random effect farm of origin × year combination explains nearly no variance. This indicates that the farm of origin does not influence the occurrence of osteochondral lesions at the end of the station test significantly. Concerning osteochondral lesions at CMH, the litter effect explains a minor proportion of the total variance. This means that pigs of the same litter show more frequently OC lesions than one would expect due to the identical parentage. Environmental effects, e.g. low milk production of the nursing dam, could be a potential explanation for this observation. But on the other hand no noticeable litter effect was observed for DEU and CMF.

Kadarmideen *et al.* (2004) estimated very low heritabilities for osteochondral lesions using linear mixed sire models except for RUP and CMF. But the authors used threshold models too. Heritabilities obtained from these threshold models ranged between $h^2 = 0.00$ (FK) and $h^2 = 0.42$ (CMH). Transformed to the 'observed scale', these heritabilities are in good agreement with the values of the present study except for DEU, which was not significantly different from zero in the study of Kadarmideen *et al.* (2004).

Jørgensen and Andersen (2000) estimated heritabilities of OC at six different positions of the carcass. The values ranged from $h^2 = 0.08$ to 0.39 and varied sometimes between Danish Yorkshire and Landrace breeds at the same position of the carcass. On average, the heritabilities in Danish populations were higher than in the present study. Differences between Danish and Swiss populations might be a potential reason. Obviously, there were distinctions between Danish breeds. We did not estimate genetic parameters of the three Swiss breeds separately, because less than 500 SLR and SLW$_{SL}$ test animals had OC data, respectively. Moreover, phenotypic variation of OC was more pronounced in Danish populations compared with the present study. Jørgensen and Andersen (2000) examined both sides of the animal radiologically for osteochondral lesions and analysed the average score statistically. The different methods of examination might have affected the incidence and variation of OC and could be another cause of different heritabilities.

Table 7 presents the results of the multivariate estimation of genetic parameters. Phenotypic correlations of osteochondral lesions to exterior and production traits were close to zero. Heritabilities of osteochondral lesions changed slightly due to the multivariate estimation in comparison to the univariate analyses. Linearly described exterior traits showed low heritabilities (0.10 to 0.20). But all values differed significantly from zero. CL and the PPC exhibited the highest heritabilities of all traits (0.61 and 0.62, respectively). Serenius *et al.* (2001) estimated lower heritabilities for leg weakness symptoms in comparison to our findings. The present results are in good agreement with Jørgensen and Andersen (2000).

Genetic correlations between osteochondral lesions at CMH, DEU and CMF were low ($r_g = -0.14$ to 0.13). This indicates that the occurrence of osteochondral lesions at the three positions does not seem to be controlled by identical genes and should be considered as different traits. This conclusion agrees with Jørgensen and Andersen (2000) and Kadarmideen *et al.* (2004).

The genetic correlations of osteochondral lesions to ADG and PPC were very low. Only the unfavourable genetic

correlation between osteochondral lesions at CMF and ADG exceeded $r_g = \pm 0.15$ in the present study. Thus, genetic selection that favours leaner and faster growing pigs does not seem to increase the genetic predisposition to exhibit osteochondral lesions considerably in Swiss breeds. Our results are in agreement with Lundeheim and Rydhmer (1990), Jørgensen and Andersen (2000) and Kadarmideen *et al.* (2004). Those authors estimated few unfavourable genetic correlations with moderate magnitude between OC and production traits. In the same way, Jørgensen (1995) did not find different prevalences of OC between pigs fed restricted *v. ad libitum* although the pigs fed *ad libitum* grew faster. In contrast, Busch *et al.* (2006) reported that a high ADG was associated with an increased risk to exhibit OC.

Genetic correlations of osteochondral lesions at CMH, DEU and CMF to exterior traits showed low to medium values. Nearly all correlations that exceed $r_g = \pm 0.15$ were favourable concerning the actual Swiss breeding goal. Especially the occurrence of osteochondral lesions at DEU and the regularity of locomotion seem to be genetically linked ($r_g = 0.54$). Only the association between regularity at the loin and CMH was genetically unfavourable and exceeded $r_g = \pm 0.15$. Therefore, genetically favouring animals with regular locomotion and optimal exterior would reduce the occurrence of osteochondral lesions in the long-term especially at DEU.

In general, our results agree with results by Jørgensen (2000) and Jørgensen *et al.* (1995). Those authors also found slight phenotypic associations between several leg weakness symptoms and pathological changes of bones and joints. Jørgensen and Andersen (2000) estimated some moderate genetic correlations between leg weakness symptoms and OC at the femoral and humeral condyles too.

Conclusion and implications
At HK, CLH, RUP and CMF even mildly osteochondral lesions are rare in Swiss breeds. More than 10% of the pigs exhibited mostly mildly osteochondral lesion at the CMH, DEU and CMF, respectively. Thus, based on the station-tested pigs osteochondral lesions do not seem to be a severe problem in Swiss breeds at the moment. The occurrence of osteochondral lesions at CMH, DEU and CMF is heritable ($h^2 = 0.16$ to 0.18). Therefore, it is possible to reduce the prevalence of osteochondral lesions by selection in principle.

Direct selection would require examination of all tested pigs for OC lesions, which is too costly. An indirect selection based on exterior traits is difficult due to low heritabilities of OC and exterior traits and low relative weight of exterior in the overall breeding goal. But the low genetic correlations between the most important production traits (ADG and PPC) and osteochondral lesions as well as the favourable genetic correlations with Swiss exterior traits suggest that the prevalence of OC will not increase, if gilts and boars are selected according to the Swiss breeding goal.

Nevertheless, SUISAG will continue the examinations of a random sample of station-tested pigs after slaughtering to observe the further development of osteochondral lesions in the Swiss breeds directly.

References

Busch ME, Christensen G, Wachmann H and Olsen P 2006. Osteochondrosis of the elbow joint in finishers – association with growth rate and heritability. Proceedings of the 19th international pig veterinary society congress, Copenhagen, Denmark, vol. 1, p. 110.

Gianola D 1984. Theory and analysis of threshold characters. Journal of Animal Science 54, 1079–1096.

Hofer A 2004. [Consideration of exterior traits in selection.] 6. Schweine Workshop Uelzen 2004 DGFZ-Schriftenreihe 33, 66–76.

Jørgensen B 1995. Effect of different energy and protein levels on leg weakness and osteochondrosis in pigs. Livestock Production Science 41, 171–181.

Jørgensen B 2000. Osteochondrosis/osteoarthrosis and claw disorders in sows, associated with leg weakness. Acta Veterinaria Scandinavica 41, 123–138.

Jørgensen B and Andersen S 2000. Genetic parameters for osteochondrosis in Danish Landrace and Yorkshire boars and correlations with leg weakness and production traits. Animal Science 71, 427–434.

Jørgensen B, Arnbjerg J and Aaslyng M 1995. Pathological and radiological investigations on osteochondrosis in pigs, associated with leg weakness. Journal of Veterinary Medicine, Series A 42, 489–504.

Kadarmideen HN, Schwörer D, Ilahi H, Malek M and Hofer A 2004. Genetics of osteochondral disease and its relationship with meat quality and quantity, growth and feed conversion traits in pigs. Journal of Animal Science 82, 3118–3127.

Kovač M, Groeneveld E and García-Cortés LA 2002. VCE-5, a package for the estimation of dispersion parameters. Proceedings of the seventh world congress on genetics applied to livestock production, Montpellier, Communication no. 28-06.

Lundeheim N 1987. Genetic analysis of osteochondrosis and leg weakness in the Swedish pig progeny testing scheme. Acta Agriculturæ Scandinavica 37, 159–173.

Lundeheim N and Rydhmer L 1990. Genetic analysis of osteochondrosis and leg weakness in the Swedish Landrace pig population. Proceedings of the fourth world congress on genetics applied to livestock production, Edinburgh, vol. XV, pp. 493–496.

Olsson S–E and Reiland S 1978. The nature of osteochondrosis in animals. Summary and conclusions with comparative aspects on osteochondritis dissecans in man. Acta Radiologica (Suppl.) 358, 299–306.

Robertson A and Lerner IM 1949. The heritability of all-or-none traits: liability of poultry. Genetics 34, 395–411.

Schwörer D, Häni HJ and Blum JK 1985. [Leg weakness symptoms and abnormalities of joints in fattening pigs]. Der Kleinviehzüchter 33, 634–644.

Schwörer D, Lorenz D and Rebsamen A 1991. [Impact of healthy limbs in pig breeding.] Der Kleinviehzüchter 39, 781–795.

Serenius T, Sevón-Aimonen M-L and Mäntysaari EA 2001. The genetics of leg weakness in Finnish Large White and Landrace populations. Livestock Production Science 69, 101–111.

S-PLUS 1999. S-PLUS, 2000 user's guide. Seattle, Washington.

SUISAG 2006. [Annual report.] http://www.suisag.ch.

Tarrés J, Bidanel JP, Hofer A and Ducroq V 2006. Analysis of longevity and exterior traits on Large White sows in Switzerland. Journal of Animal Science 84, 2914–2924.

Van Steenbergen EJ 1990. Relevance of exterior appraisal in pig breeding. PhD thesis, Wageningen University, The Netherlands.