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Osteochondrosis lesions: Heritabilities and genetic correlations to production and exterior traits in Swiss station-tested pigs

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Introduction

Osteochondrosis (OC) is a disturbance of the enchondral ossification as well in the joint cartilage as in the growth plates (Olsson and Reiland, 1978). OC 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 osteochondrosis is of noticeable relevance.
It is well known that besides environmental factors genetic effects influence the occurrence of OC lesions (Kardarmideen *et al*., 2004; Jørgensen and Andersen, 2000; Lundeheim, 1987).
But a 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. a linear description of exterior characteristics – may be a preferable way to control the genetic aspects of osteochondrosis.
The aim of the present study is to estimate the heritabilities of osteochondral lesions at different positions of the carcass and the genetic correlations to some production and several exterior traits

Material and Methods

Station-Test

In Switzerland approximately 3000 animals are station-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 fullsibs (female & castrate). Animals are housed in 12 barns, each with 8 pens and about 10 animals per pen. Electronic feed dispensers are used to feed the animals *ad libitum*. The test starts with 30kg and ends with approximately 103kg. Every week, 40-70 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 30kg to 103kg describes the growth of animals. Feed conversion ratio is defined as the ratio of total weight of feed consumed during the test period to live weight gain during the test. Percentage of premium cuts (**PPC**) specifies the leanness of carcasses. PPC is defined as the weight of ham, back and shoulder without fat layer proportional to carcass weight. Several meat quality traits (intra muscular fat content, pH value 45min and 30h post-mortem and reflectance 30h post-mortem) are measured in routine, but were not included in the present study. A full description of the Swiss station-test is given in the annual report of SUISAG (2005).

Examination of bones

Osteochondral lesions were already observed at the Swiss test-station in the eighties and nineties. In 2002, SUISAG decided to examine OC lesions in a random sample of station-tested animals again, because the breeding goal was adjusted towards daily gain. A trained person examines front and hind leg bones of the slaughtered pigs and records OC lesions with scores from 1 to 4. A score of 1 denotes “no visible osteochondral lesion”. Scores 2 to 4 denote “mildly to severely affected”, respectively. OC lesions are examined at the following bones and joints: head of humerus (**HK**), condylus medialis humeri (**CMH**), condylus lateralis humeri (**CLH**), radius and ulna proximal (**RUP**) and head of femur (**FK**). OC lesions at the distal epihyseal cartilage of ulna (**DEU**) and condylus medialis femoris (**CMF**) are scored from 1 to 6, because these lesions supposed to be more variable. Figure 1 shows the corresponding positions at the carcass.

Linear description of exterior

A linear description system (LD) is 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 4 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 score 5 to 7 denote that the animals are more and more 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. The present study includes exterior examinations of station-tested animals which were performed approximately 4 to 1 week before slaughtering. In total seven trained persons described the animals during the four year 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 station-tested animals of the purebred lines LW_{DL}, SLR and LW_{SL} that were slaughtered between Jan. 2002 and Dec. 2005. Table 1 shows the distribution of the animals and table 4 presents the average fattening and carcass performance of the station-tested animals. The test animals are progeny of 1051 sires and 19988 animals are included in the pedigree file.
About 27% of all slaughtered animals were examined for osteochondral lesions (N = 2622). The number of observations was slightly reduced at RUP and DEU, because these bones were used for another project. Table 2 shows the distribution of OC lesions at different positions.
Data from linear description was available for nearly all animals. Approximately fifty test animals had no or incomplete exterior data due to different reason (e.g. clinical lameness at description day, etc.). Table 3 shows the distribution of the scores.

Statistical analysis

Genetic parameters were estimated with univariate and multivariate linear mixed animal models using VCE5 (Kovač *et al*., 2002). Besides osteochondral lesions and exterior traits only ADG and PPC were investigated due to computational limitations. Estimations of heritabilities and genetic correlations of the 17 traits were performed in 14 separated 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:

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

PPC, CL:

$$y_{hjmnopq} = \mu + BREED_h + SL\_DAY_j + SEX_m + b_m\, LW_{hjmnopq} + farm\_y_n + litter_o + animal_p + e_{hjmnopq}$$

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

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

HK, CMH, CLH, RUP, DEU, FK, CMF:

$$y_{hkmnopq} = \mu + BREED_h + SL\_PER_k + SEX_m + b_m\, LW_{hkmnopq} + farm\_y_n + litter_o + animal_p + e_{hkmnopq}$$

with:

y	observation of test animal q	(q = 1, 2, ...,9511)
μ	overall mean	
$BREED_h$	fixed effect of breed	(h = LW_{DL}, SLR, LW_{SL})
$BARN\_PER_i$	fixed effect of barn x period combination	(i = 1, 2, ..., 149)
SL_DAY_j	fixed effect of slaughter day	(j = 1, 2, ..., 213)
SL_PER_k	fixed effect of slaughter period	(k = 1, 2, ..., 8)
LD_PE_l	fixed effect of the person performing the LD	(l = 1, 2, ..., 7)
SEX_m	fixed effect of sex	(m = female, castrate)
$LW(SEX_m)$	partial linear regression on live weight within sex	
$farm\_y_n$	random effect of farm of origin x year combination	(n = 1, 2, ..., 249)
$litter_o$	random effect of the litter	(o = 1, 2, ..., 4763)
$animal_p$	random effect of the animal	(p = 1, 2, ..., 19988)
e	random error	(q = 1, 2, ..., 9511)

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 OC lesions traits, because only approximately 10-15 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. Pre-corrected values were used for ADG. Therefore no regression on live weight was included in the model. No correction for live weight was possible for exterior traits, because pigs were not weighed at the description day.

Results and Discussion

The occurrence of osteochondral lesions varies at different positions of the carcass (table 2). Very few animals showed OC 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 Kardamideen *et al*. (2004). The authors used a sub dataset of this study that included only test animals slaughtered in 2002 and 2003. Jorgensen *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 OC 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 osteochondrosis at the humeral condyles and an explicit 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. Jørgensen (1995) found no significant differences between sexes concerning osteochondrosis, which is in good agreement to our findings (results not shown).
Differences between breeds were moderate and inconsistent at different positions of the carcass (table 5). Swiss Landrace showed more osteochondral lesions at CMF but slightly less at RUP compared to 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.

Conspicuous phenotypic variation was observed in all traits of the linear description of exterior characteristics (table 3). The scores of X-O at rear legs show almost a Gaussian distribution with an average of 3.46. Thus, it is necessary to reduce the X posture of the rear legs in the Swiss population. Approximately 77% of all animals exhibited an optimal side view angle of rear legs (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 to the outside claw. 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 six months of age for leg weakness symptoms. A lot of Danish gilts showed uneven claws especially in crossbred sows. Thus, smaller inner claws seem to be common in different pig populations and it will be necessary to equal the size of both claws in the future.
Approximately 55% of the Danish gilts exhibited a posture of rear legs called "turned out", which is identical to the Swiss synonym "X posture" and 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. Otherwise, Jørgensen and Andersen (2000) observed only approximately 5% weak pasterns but about 80% to 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 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 each osteochondral lesion without influence of other traits (table 6). Phenotypic variances of OC lesions at HK, CLH and FK are very low. RUP shows a minor phenotypic variance. But all four heritabilities are low, because the additive genetic variances are close to zero. Substantial phenotypic and additive genetic variances were estimated for osteochondral lesions at CMH, CLH and especially DEU. Thus, heritabilites range from h^2=.16 to h^2=.18. The corresponding standard errors are low.
Kardarmideen *et al*., (2004) estimated very low heritabilities for osteochondral lesions using linear mixed sire models except for RUP and CMF. But the authors used general linear mixed models too. Heritabilities of these threshold models ranged between h^2= .00 (FK) and h^2= .42 (CMH). Transformed to the "observed scale", these heritabilities are in good agreement with the values of the present study except for DEU.
Jørgensen and Andersen (2000) estimated heritabilities of osteochondrosis at six different positions of the carcass. The values ranged from h^2= .08 to h^2= .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. On the one hand, differences between Danish and Swiss populations might be a potential reason. Obviously, there are distinctions between Danish breeds. We did not estimated genetic parameters of the three Swiss breeds separately, because less than 500 SLR and SLW_{SL} test

animals exhibited OC data, respectively. On the other hand, phenotypic variation of osteochondrosis was more pronounced in Danish populations compared to 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 osteochondrosis between both studies and could be a second 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 are close to zero. Heritabilities of OC lesions changed slightly due to the multivariate estimation in comparison to the univariate analyses. Exterior traits of the linear description system show low heritabilities. But all values differ significantly from zero. Carcass length and PPC exhibit the highest heritabilities of all traits. 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 (r_g) of osteochondral lesions at HK, CLH, RUP and FK to all other traits should not be regarded at all, because these osteochondral lesions show almost no genetic variance in univariate and multivariate estimations.

Genetic correlations between osteochondral lesions at CMH, DEU and CMF are low (r_g = -.14 to .13). This indicates that the occurrence of OC lesions at the three positions doesn't seem to be controlled by identical genes and should be considered as different traits. This conclusion agrees with Jørgensen and Andersen (2000) and Kardamideen *et al*. (2004).

The genetic correlations of osteochondral lesions at CMH, DEU and CMF to average daily gain (ADG) and PPC are very low. Only the unfavourable genetic correlation between osteochondral lesions at CMF and ADG exceeds $r_g = \pm .15$ in the present study. Thus, a selection that favours leaner and faster growing pigs doesn't seem to increase the genetic predisposition to exhibit osteochondral lesions at CMH, DEU and CMF considerably in Swiss breeds. Our results are in agreement with Lundeheim and Rydhmer (1990), Jørgensen and Andersen (2000) and Kardamideen *et al*. (2004). The authors estimated few unfavourable genetic correlations with moderate magnitude between osteochondrosis and production traits. In the same way Jørgensen (1995) did not find different prevalences of osteochondrosis between pigs fed restricted versus *ad lib*., although the pigs fed *ad lib*. grew faster. In contrast, Busch *et al*. (2006) reported, that a high ADG is associated with an increased risk to exhibit osteochondrosis.

Genetic correlations of osteochondral lesions at CMH, DEU and CMF to exterior traits of the linear description show low to medium values. Nearly all correlations that exceed $r_g = \pm .15$ are favourable concerning the actual Swiss breeding goal. Especially the occurrence of OC lesions at DEU and the manner of locomotion seem to be genetically linked (r_g = .54). Only the association between regularity at the loin and CMH is genetically unfavourable and exceeds $r_g = \pm .15$. Therefore, favouring animals with regular locomotion and optimal exterior would reduce the occurrence of osteochondral lesions on long-term especially at DEU.

These results agree with Jørgensen (2000) and Jørgensen *et al*. (1995). The authors 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 osteochondrosis at the femoral and humeral condyles too.

Conclusion

Swiss station-tested pigs were examined for several exterior traits before slaughtering and osteochondral lesions at seven positions of the carcass after dissection. The prevalence of mildly OC lesions was low ($\leq$6%) at four positions. These positions show nearly no genetic variances and the heritabilities are close to zero. Osteochondral lesions at CMH, DEU and

CMF exhibit phenotypic and genetic variance. Thus, heritabilities range from .16 to .18. The heritabilities might be higher, if threshold models would have been used due to the categorical distribution of osteochondral lesions especially at CMH and CMF.
Exterior traits of the Swiss linear description system show low heritabilities (.10 - .26) but several favourable genetic correlations to osteochondral lesions at CMH, DEU and CMF with low to moderate magnitude. Genetic correlations between osteochondral lesions and production traits (ADG, PPC) are low.
Of course, it is difficult to reduce osteochondral lesions considerably by indirect selection on exterior traits due to low heritabilities, low genetic correlations and low relative weight of exterior in the overall breeding goal. But the Swiss linear description system of exterior traits seems to be a good tool to control leg weakness symptoms at the breeding farms that are partly caused by osteochondral lesions. 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.

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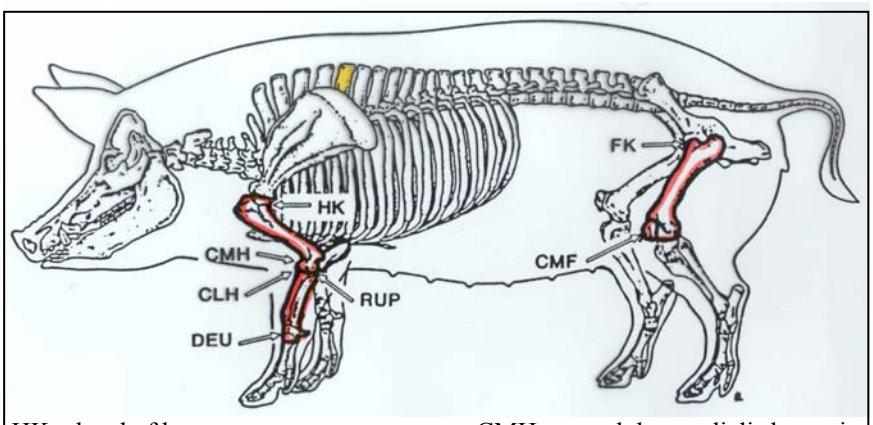
Appendix



HK: head of humerus
CMH: condylus medialis humeri
CLH: condylus lateralis humeri
RUP: radius and ulna proximal
DEU: distal epiphyseal cartilage of ulna
FK: head of femur
CMF: condylus medialis femoris

Figure 1: Examinations of osteochondral lesions at the test-station

type

	score	4	5	6	7
regularity at the loin LOIN		regular			very narrow

rear legs

	score	1	2	3	4	5	6	7
X-O XORL			X posture				O posture	
side view angle SVARL			claw position in front of the knee joint				claw position behind of the knee joint	
angle of pastern APRL			weak				steep	
size of inner claw SICRL			smaller				larger	

fore legs

	score	1	2	3	4	5	6	7
side view angle SVAFL			backward				forward	

locomotion

	score	4	5	6	7
LOC.		regular			stiff or lurching

Figure 2: Scheme of the Swiss linear description system (without teat description)

Table 1: Distribution of station tested animals

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: Distribution of the scores of osteochondral lesions

score	HK	CMH	CLH	RUP	DEU	FK	CMF
1	2589	2339	2577	2401	335	2617	1872
2	25	231	39	161	991	4	709
3	8	52	6	1	724	1	37
4	0	0	0	0	390	0	4
5					122		0
6					2		0
total	2622	2622	2622	2563	2564	2622	2622
mean	1.02	1.13	1.02	1.06	2.60	1.00	1.30

Abbreviations: see figure 1

Table 3: 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

Abbreviations: see figure 2

Table 4: Mean and distribution of performance traits

Trait	N	Mean	SD	Min.	Max.
LW [kg]	9511	103.33	3.51	85.50	118.60
ADG [g/d]	9511	865.38	94.10	544.60	1218.00
FCR [kg/kg]	9511	2.58	0.21	1.99	3.58
FI [kg/d]	9511	2.23	0.24	1.45	3.21
TFI [kg]	9511	190.39	15.27	141.60	260.00
CL [cm]	9510	96.95	2.82	85.00	110.00
PPC [%]	9511	57.66	2.54	46.98	65.90
IMF [%]	9511	2.06	0.60	0.92	7.74
pH45 [value]	9511	6.30	0.17	5.42	6.83
pH30 [value]	9511	5.41	0.04	5.26	6.61
H30 [value]	9511	33.15	2.90	22.00	53.00

LW = live weight at slaughtering; ADG = average daily gain (30-103kg)
FCR = feed conversion ratio; TFI = total feed intake during test
FI = average daily feed intake; LC = length of carcass
PPC = percentage of premium cuts; IMF = intra muscular fat content
pH45 = pH value 45 minutes (pH30 = 30h) post-mortem
H30 = reflectance 30 hours post-mortem

Table 5: Distribution of osteochondral lesions within breeds

HK	LW_{DL}	SLR	LW_{SL}	LW_{DL}	SLR	LW_{SL}
1	1725	408	456	98.68%	99.03%	98.70%
2	16	4	5	0.92%	0.97%	1.08%
3	7		1	0.40%	0.00%	0.22%
CMH	LW_{DL}	SLR	LW_{SL}	LW_{DL}	SLR	LW_{SL}
1	1554	378	407	88.90%	91.75%	88.10%
2	156	29	46	8.92%	7.04%	9.96%
3	38	5	9	2.17%	1.21%	1.95%
CLH	LW_{DL}	SLR	LW_{SL}	LW_{DL}	SLR	LW_{SL}
1	1722	399	456	98.51%	96.84%	98.70%
2	24	12	3	1.37%	2.91%	0.65%
3	2	1	3	0.11%	0.24%	0.65%
RUP	LW_{DL}	SLR	LW_{SL}	LW_{DL}	SLR	LW_{SL}
1	1600	391	410	93.35%	97.02%	91.93%
2	113	12	36	6.59%	2.98%	8.07%
3	1			0.06%	0.00%	0.00%
DEU	LW_{DL}	SLR	LW_{SL}	LW_{DL}	SLR	LW_{SL}
1	235	58	42	13.71%	14.39%	9.40%
2	677	157	157	39.50%	38.96%	35.12%
3	477	117	130	27.83%	29.03%	29.08%
4	253	50	87	14.76%	12.41%	19.46%
5	72	19	31	4.20%	4.71%	6.94%
6		2		0.00%	0.50%	0.00%
FK	LW_{DL}	SLR	LW_{SL}	LW_{DL}	SLR	LW_{SL}
1	1744	411	462	99.77%	99.76%	100.00%
2	3	1		0.17%	0.24%	0.00%
3	1			0.06%	0.00%	0.00%
CMF	LW_{DL}	SLR	LW_{SL}	LW_{DL}	SLR	LW_{SL}
1	1266	240	366	72.43%	58.25%	79.22%
2	460	157	92	26.32%	38.11%	19.91%
3	20	14	3	1.14%	3.40%	0.65%
4	2	1	1	0.11%	0.24%	0.22%

Abbreviations: see figure 1 and table 1

Table 6: Variance components and heritabilities (h^2) of OC lesions (univariate estimation)

Trait	variance components							
	phenotypic	farm_y	litter	**genetic**	error	c^2	$\mathbf{h^2}$	SE
HK	0.0215	0.0000	0.0001	**0.0000**	0.0205	.04	**.00**	.00
CMH	**0.1514**	0.0000	0.0102	**0.0242**	0.1170	.07	**.16**	.04
CLH	0.0235	0.0009	0.0012	**0.0004**	0.0210	.05	**.02**	.04
RUP	0.0588	0.0001	0.0030	**0.0011**	0.0546	.05	**.02**	.01
DEU	**0.9563**	0.0120	0.0119	**0.1721**	0.7602	.01	**.18**	.03
FK	0.0033	0.0001	0.0015	**0.0001**	0.0016	.44	**.04**	.04
CMF	**0.2371**	0.0070	0.0000	**0.0418**	0.1883	.00	**.18**	.03

Abbreviations: c^2 = ratio of litter variance, SE = standard error of h^2 and see figure 1

Table 7: Phenotypic correlations (above diagonal), heritabilities (diagonal) and genetic correlations (below diagonal) of multivariate analyses

	ADG	PPC	XORL	SVARL	APRL	SICRL	SVAFL	LOC.	CL	LOIN	HK	**CMH**	CLH	RUP	**DEU**	FK	**CMF**
ADG	**0.27**	-0.25	0.04	0.01	0.00	-0.03	-0.01	0.04	-0.12	0.00	-0.03	-0.01	-0.03	-0.09	0.00	-0.03	0.09
PPC	-0.07	**0.62**	-0.03	0.00	0.07	-0.01	0.07	0.02	0.17	0.24	0.01	-0.02	0.04	0.05	0.03	-0.01	-0.03
XORL	0.08	0.02	**0.13**	-0.02	-0.19	-0.01	-0.10	-0.12	-0.12	-0.02	-0.01	-0.02	-0.01	-0.01	0.02	-0.03	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	-0.03	-0.01	0.01	0.02	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	0.02	0.02	-0.01	-0.04	0.00	-0.01
SICRL	0.00	-0.08	-0.17	0.18	0.08	**0.15**	-0.04	-0.11	-0.06	-0.05	0.00	-0.03	-0.01	-0.01	-0.01	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	-0.02	-0.03	0.02	0.03	0.02	0.00	0.02
LOC.	0.30	-0.05	-0.12	-0.57	0.03	-0.29	0.20	**0.14**	0.04	0.13	0.00	0.01	0.03	0.00	-0.01	-0.03	0.03
CL	-0.10	0.17	-0.25	-0.17	-0.09	-0.06	0.28	-0.06	**0.61**	0.01	0.00	-0.03	-0.01	0.04	-0.03	0.02	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	0.00	0.00	0.00	0.00
HK	0.70	-0.06	-0.55	-0.09	-0.62	-0.15	0.25	0.50	0.10	0.39	**0.01**	-0.02	0.03	0.03	-0.02	-0.02	0.04
CMH	-0.11	0.06	-0.17	-0.27	-0.04	-0.16	-0.01	0.16	-0.07	-0.20	-0.03	**0.17**	-0.01	0.02	0.01	-0.01	0.06
CLH	0.11	0.23	-0.38	0.76	-0.09	-0.20	0.04	0.60	-0.12	-0.03	0.49	-0.41	**0.04**	0.02	-0.02	0.01	0.07
RUP	-0.09	0.26	-0.60	-0.21	-0.21	-0.11	0.63	0.27	0.73	0.44	0.51	0.38	-0.16	**0.03**	0.04	0.07	-0.02
DEU	0.01	0.06	0.01	-0.15	-0.11	-0.20	-0.09	0.54	-0.07	0.18	-0.08	0.13	0.03	-0.05	**0.17**	0.04	0.01
FK	-0.24	-0.16	-0.25	0.07	0.02	-0.76	0.42	-0.07	0.05	0.08	-0.04	0.02	-0.50	0.77	0.17	**0.06**	0.02
CMF	0.21	0.11	0.11	-0.14	-0.12	-0.25	-0.03	0.27	0.12	0.20	0.40	-0.14	0.18	0.04	-0.10	-0.10	**0.17**

Abbreviations: see figure 1, 2 and table 4

underlined values: notable genetic correlation is favourable concerning the actual Swiss breeding goal ($r_g \geq \pm.15$)

shaded values: notable genetic correlation is unfavourable concerning the actual Swiss breeding goal ($r_g \geq \pm.15$)