56th Annual Meeting of the European Association for Animal Production
June 5-8 2005, Uppsala, Sweden

Commission of Horse Production
Session HM5.7-Performance and health in young horses

Evaluation of breeding strategies against osteochondrosis (OC) in warmblood horses

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Abstract

Osteochondrosis (OC) is a skeletal disease caused by disturbed bone formation and can lead to loose bone fragments in the joints (OCD). Affected horses have a higher risk for locomotion problems and culling (Koenen, 2000). The frequency of OC is up to a quarter in different warmblood breeds. Heritability estimates for OC range from 0,1 to 0,3 and indicate that genetic selection can reduce the frequency of OC (Bruns, 2001). In the present study, breeding strategies against OC are simulated for a breeding population with 5.000 mares and 100 stallions and 20.000 foals per generation. The selection considers three different traits (Dressage, Jumping, OC). Different genetic models are developed. The first one step selection model assumes OC affected by an autosomal gene with two allels, in the second model OC is assumed as a all-or-none phenotypic trait with an underlying normally distributed genotype. Moreover a two-step selection model is developed. At first horses are selected based on their performance in dressage and jumping. Secondly horses are tested for OC by x-rays. This model is refined to divide the phenotype into the 4 common x-ray classes. Within 5 generations the changes of the genotype frequency of OC due to selection are observed. First results show that the genotype frequency of OC decreases more rapidly by using the first model.

Key Words: Osteochondrosis, horses, breeding strategy, simulation

Introduction

Locomotor problems are shown to be the most common cause of culling adult horses (Philipsson, 2000). This is why osteochondrosis is one of a major problem in the present econonomic market of horses (Ricard, 2004). When the horse has been trained to perform as a show jumper or dressage horse with top performance at 10-15 years of age large investments have been made to reach these levels. It is therefore quite essential that the horse has such constitutional qualities for staying sound to utilize its potential to perform. Animal welfare further supports the importance of healthy horses as it is a part of the breeding goal of warmblood populations. The breeding goal for riding horses of the german warmblood associations aims at high level sport performance combined with good health and functional and good aesthetic conformation.

Many health problems relate to orthopaedic diseases and lesions, one of the important diseases is osteochondrosis (Koenen, 2000).
OC is characterised by a disturbance in the process of endochondral ossification. This process takes places in the young growing animal. During this process cartilage is mineralised and transformed into bone. Due to the disturbance, cracks and fissures occur in the degenerated and necrotic parts of the cartilage. Finally, under biomechanical loading fragments may be formed that can separate and become so-called joint-mice or chips. The mostly affected joints are fetlock, hock and stifle, but though less frequent, OC has been found in almost every synovial joint of the horse (van Weeren, 2002). Pathogenesis and aetiology of OC are still unclear and appear to be multifactorial (Jeffcott, 1991) affected by locomotion, growth rate, sex, nutrition and heredity factors.
Correlations between osteochondrotic findings and conformation traits as well as performance traits are of special interest for horse breeding. The results of an interdisciplinary research project show a negative correlation between OC in the fetlock joint and OC in the hock. The estimated correlations between OC and conformation traits as well as performance traits tend to zero and are regarded as statistically insignificant (Schober, 2003).
The efficiency of present selection strategies on the reduction of the frequency of OC has not yet been evaluated. Moreover, knowledge on the effect of selection against OC on the genetic improvement of sport performance is lacking. Therefore, the aim of this study is to evaluate the effect of applicable selection strategies on the frequency of OC and on the genetic trend for sport performance. As a result, recommendations for the implementation of the selection against OC in actual breeding programs should be given to the breeding associations.

Material and Methods

In this study selection strategies against OC are simulated for a breeding population with 5000 mares and 100 stallions. Every mare produces 2 fillies and 2 colts per generation, so that in total 20.000 foals are available for selection which may be applied for male foals only or for both sexes. Within 5 generations the changes of the genotype frequency of OC due to selection are observed, as well as changes in breeding values of the performance traits (dressage, jumping) averaged over 50 repetitions.
So far two different genetic models for the definition of osteochondrosis are developed.
Model I describes OC as an one-gene locus trait with two allels. Due to the fact that the transmission of OC is unknown, an autosomal recessive model is assumed (aa = OC affected, Aa and AA = OC not affected). The penetrance can be considered to simulate that not all genetically affected horses are diagnosed as affected on the basis of x-rays. So, the phenotype of OC shows two groups, OC positive and OC negative.
In model II the OC genotype (additive genetic) is simulated as a normally distributed trait. Due to the frequency of OC a fixed border line is defined that divides the phenotypes in two classes: OC positive or OC negative. Correlations between OC and performance traits as well as environmental influences can be implemented in this model. The two performance traits simulated may be considered as the performance in dressage and jumping; their genotypes (additive genetic) and phenotypes are normally distributed traits (NID 0,1).

Two different selection strategies are applied for both different genetic models. The one-step selection model selects horses for the three different traits within one step. In this strategy all horses are x-rayed for OC. The two step selection model selects horses based on their performance in dressage and jumping at the first step; at the second step horses are selected on both the performance in dressage and jumping and on OC. Only the superior horses in dressage and jumping are x-rayed for OC.

Moreover this two-step selection model has been refined to divide the phenotype into the 4 common x-ray classes. These selection procedures resemble the real situation in warmblood populations whereby the selection intensity at the two steps can be defined. The two-step selection model is of practical relevance since it reduces the costs for radiological observations.
The selection criterion is defined as a multitrait selection index which combines the phenotypic and/or the additive genetic effects of the traits simulated. The weights given to the performance traits follow the heritability and are set to 0.4 and 0.4 for dressage and jumping, and 0.2 for OC respectively.

Results

Assuming selection in real populations is based on the phenotypes of horses, i.e. on OC identified by X-rays and on scores describing the performance of each horse in dressage and jumping. The three phenotypic traits are available on all horses within a generation.
Table 1 shows the selection responses of the described genetic models by using the same selection model after 4 rounds of selection.

Table 1: Reduction of OC frequency after 4 cycles of selection

Selection procedure [1]	**Genetic model OC**	**OC frequency in the 5th generation**	
		mean [2]	**std. dev.**
One step	Gene locus model	0.109	0.021
	Normally distributed	0.171	0.005
Two step	Gene locus model	0.087	0.021
	Normally distributed	0.181	0.002
Two step [3]	Normally distributed [3]	0.137	0.009

[1] weight given to dressage, jumping and OC are .4; .4; .2 respectively
[2] mean frequency of OC in generation 1=0.2
[3] four phenotypic OC classes

The selection against OC described as a one-locus trait reduces the phenotypic frequency of OC from 20% in the first generation to 11% in the fifth generation. A substantial reduction in the OC-frequency is possible assuming OC is identified on all horses. The weights given to each trait resemble the heritability. Defining OC as a all-or-none trait with an underlying genetic normal distribution the phenotypic frequency of OC is reduced from 20% in the first generation to 17% in the fifth generation. Based on this genetic model of OC much less selection response can be realized.
Applying the two-step selection with equal selection rates of .1 at the first and second step for selecting stallions similar response rates are achieved as in the one-step selection. In fact when defining OC phenotypically in four classes greater reduction in the OC frequency is achieved compared with OC defined in two classes (0.137 vs. 0.171 or 0.181).

Selection against OC in real populations is costly. Keeping costs for OC identification small, selection can be organised in different steps. The first step considers selection for performance traits such as dressage and jumping, the second step includes information on OC in addition to dressage and jumping.

Table 2 shows the effect of different selection rates on the reduction of the OC frequency by using the two-step genetic model II with four phenotypic classes after 4 selection cycles.

Table 2: Changes in OC frequency according to different selection rates

Selection rate (stallions) [1]		**OC frequency in the 5th generation**	
first step	**second step**	**mean** [2]	**std.dev.**
.01	1	0.175	0.005
.02	.5	0.143	0.005
.05	.2	0.137	0.009
.1	.1	0.137	0.009
.2	.05	0.137	0.009
1	.01	0.137	0.009

1) weigth given to dressage, jumping and OC are .4;.4;.2 respectively
2) mean frequency of OC in generation 1=0.2

The results in table 2 show, that increasing selection pressure against OC (smaller selection rate at second step), leads to more progress in the reduction of OC frequency, which also means that more horses are tested for OC by x-rays. The highest progress in the reduction of OC frequency is reached by using a replacement rate of .05 at the first step and .2 at the second step. Further increasing selection pressure against OC does not lead to any more progress in the OC frequency reduction.

Another aim of this study is to evaluate the effect of different selection weights against OC on the genetic trend for sport performance. Table 3 shows the selection response in all normally distributed traits (two-step selection model II with four phenotypic classes) when applying different selection weights in defining the selection index.

Table 3: Selection response in normally distributed traits of genetic model II, applying different selection weights

Selection weights			**Changes in averaged breeding values** [1]		**Changes in OC frequency** [2]
Dressage,	**Jumping,**	**OC**	**Dressage**	**Jumping**	
.4	.4	0	1.669	1.717	0.005
.4	.4	.2	1.530	1.596	-0.063
.4	.4	.4	1.394	1.440	-0.094
.4	.4	.8	1.196	1.278	-0.098

1) differences in averaged breeding values estimated as mean breeding value 5th generation minus mean breeding value 1st generation
2) differences in averaged phenotypically frequency estimated as mean frequency 5th generation minus mean frequency 1st generation

The results in table 3 show that the breeding values of dressage and jumping change in relation to the reduction of the frequency of OC. The more progress is made in the reduction of the OC frequency, the less progress is achieved in the breeding values of the performance traits. So, in simultaneously selecting for sport performance and against OC the relative weights given to the selection traits influence the progress in each trait.

Discussion and Conclusion

In the present study on osteochondrosis a selection program was developed in Fortran 77 to evaluate breeding strategies against OC. Two different genetic models have been applied so far. These models were tested in many different selection variations against OC. First results show, that the frequency of OC decreases more by using the one-locus model I as compared to model II in which OC is described as a all-or-none trait with an underlying genetic normal distribution. Under model II OC is described as a usual biological variable which is affected by many environmental factors besides the genetic ones. However, under model I the difference between the genotype and phenotype of OC is only explained by the effect of penetrance. Therefore selection against OC under model I is less disturbed by environmental factors as compared to model II and therefore more responsive. The small selection response under model II indicates the great difficulties of reducing the frequency of OC in real populations when selecting against OC described phenotypically in two classes (OC positive and identified by common x-ray procedures and OC negative) and for other performance traits at the same time.

In the two-step selection model the selection against OC takes place at the second step, after horses already have been selected for their performance in dressage and jumping, so that the selection is based on less horses, which leads to a smaller reduction of the frequency of OC, as shown in the results of table 1. On the other hand this selection model leads to lower costs for radiological observations.

Different selection rates lead to changes in the reduction of OC. A higher selection rate on the first selection step gives more room for selection against OC and therefore leads to more progress in the reduction of the OC frequency. The highest progress is achieved by using a selection rate of .05. Due to this result, the recommendation can be given to breeders, to use a selection rate of 5 to 10% at the first step and 20 to 10% at the second step. This will lead to substantial reduction in the OC frequency at reasonable costs.

The evaluation of the genetic trend of performance traits show that a reduction of the OC frequency goes together with less progress in breeding values of dressage and jumping, because a stronger consideration of one trait in a multitrait selection index leads to less progress in the breeding values of the other considered traits.

In view of these results the conclusion can be drawn, that a higher reduction of OC frequency goes at the expense of lower breeding progress in performance traits or higher costs for radiological observations to test all horses for OC by x-rays.

Further genetic models of OC will be tested, such as using more values describing the degree of the disease either in the fetlock or in the hock or in both joints. Then the selection will be based on estimated breeding values of OC and of the performance traits calculated from an animal model. Recent progress in molecular genetics might provide the chance to identify the chromosomal regions that determine the liability for OC. If such genetic markers are identified, marker assisted selection or a gene test might accelerate the reduction in the frequency of OC, as it is shown above in the example. The appropriate selection strategy can also be implemented into the two-step selection model.

Due to the fact, that OC is a serious problem in sport-horse breeding which means big economic losses for breeders and owners, the selection against this disease should be implemented in nowadays breeding programs. This simulation study will help identifying the appropriate selection program to be applied by breeding organizations.

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