Institutionen för husdjursgenetik

Genetic Analysis of Stifle Arthrosis in Swedish Boxer Dogs

by

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Examensarbete 284
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Agrovoc: Dogs, bone diseases, quantitative genetics, genetic parameters

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Examensarbete ingår som en obligatorisk del i utbildningen och syftar till att under handledning ge de studerande träning i att självständigt och på ett vetenskapligt sätt lösa en uppgift. Föreliggande uppsats är således ett elevarbete och dess innehåll, resultat och slutsatser bör bedömas mot denna bakgrund. Examensarbete på D-nivå i ämnet husdjursgenetik, 20 p (30 ECTS).

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Sammanfattning

Knäledsproblem hos boxer är ett känt problem i Sverige och har diskuterats i boxerkretsar länge. Svenska Kennelklubben (SKK) har sedan 1997 ett hälsoprogram för att minska förekomsten av knäledsartros hos boxer.

Denna studie baseras på information från SKK omfattande röntgenutlåtanden avseende knäleder, armbågsleder och höftleder för svenska boxerhundar undersökta mellan åren 1989 till maj 2005. Antalet hundar med röntgenresultat för knäleder, höftleder och armbågar var 3990, 4197, respektive 390. Materialet sammanställdes mot härstamningsfilen för boxrar registrerade i SKK omfattande 26943 hundar. I studien finns även information och statistik från försäkringsbolaget Agria

Från 1992 till 2005 har andelen hundar drabbade av knäledsartros minskat från 18 % till 6 %. Andelen röntgade hundar har ökat från 36% 1992 till ca 65 % röntgade under år 2005 av antalet registrerade hundar. Antalet boxrar som registreras i SKK har varit stabilt under de senaste femton åren och ligger på ungefär 550 nyregistrerade hundar om året.

För att kunna avgöra hur stor del av den fenotypiska variationen avseende knäledsartros och höftledsdysplasi som beror på genetisk variation har arvbarheter för dessa egenskaper skattats. Den genetiska analysen av materialet visade arvbarheter på 0,11 ± 0,04 för knäledsartros och 0,28 ± 0,03 för höftledsdysplasi (HD). Det var signifikant fler hanhundar som drabbades av knäledsartros än tikar. Risken för knäledsartros och höftledsdysplasi ökar signifikant med ökad ålder vid röntgen. Andelen hundar med höftledsdysplasi ökade signifikant under de senaste åren. Den genetiska korrelationen mellan knäledsartros och HD var låg och icke signifikant (0,09 ± 0,14). Armbågsledsartros (AD) är ett mycket litet problem för boxer och det fanns få röntgade hundar i materialet. Därför har ingen genetisk analys gjorts av AD i den här studien.

Materialet från försäkringsbolaget Agria visade att antalet boxrar med knäledsrelaterade problem minskade men inte i samma takt som för alla raser sammanslaget. Antalet boxrar för vilka livförsäkringen hade tagits ut på grund av knäledsskador minskade dock mer än för alla raser sammanslaget.

SKK:s hälsoprogram för boxer har resulterat i en minskning av antalet unga boxer som drabbas av knäledsartros. Hur statusen för de äldre hundarna ser ut bör man kunna se i materialet från försäkringsbolaget Agria där minskningen inte är lika stor för boxer som för alla andra raser sammanslaget.

I framtiden är det viktigt för aveln av svenska boxrar att fortsätta med arbetet att röntga knäleder och registrera resultatet. Dessutom bör man i aveln enbart använda avelsdjur utan anmärkning på knäleder och aktivt utvärdera avkommornas röntgenresultat för knälederna.

Abstract

Stifle problems in Boxer dogs have been a major issue in discussions in Swedish boxer breeding circles for a long time. Since 1997, the Swedish Kennel Club (SKC) has a genetic health programme for boxers to reduce the number of dogs affected by stifle arthrosis.

This study is based records from the SKC on radiographic evaluations of stifle, elbow and hip joints of Swedish boxer dogs between the years 1989 to May 2005. The number of radiographed stifle joints, hip joints and elbow joints were 3990, 4197 and 390, respectively. This material was merged with a pedigree file including 26943 boxers. The study also contains information and statistics on insured boxers from the insurance company Agria

From 1992 to 2005 the proportion of Boxers with stifle arthrosis has decreased from 18% to 6%. The proportion of radiographed dogs has increased during the period studied from 36% in 1992 and was in 2005 about 65% of the registered Boxers. The number of registered boxers in Sweden during the last fifteen years has been stable around 550 dogs per year.

To be able to estimate how much of the phenotypic variation in a trait that depends on genetic variation the heritability must be calculated. The genetic analysis of this material showed heritabilities for stifle arthrosis of 0.11 ± 0.04 and for hip dysplasia (HD) 0.28 ± 0.03. There were significantly more male dogs affected of stifle arthrosis than female dogs. Furthermore, there was a significantly higher risk of stifle arthrosis and HD with increased age at screening. For HD, the effect of test year was also significant. The genetic correlation between stifle arthrosis and HD was not different from zero (0.09 ± 0.14). The number of boxers with elbow dysplasia (ED) was very low and only few had been radiographed. Therefore, in this study ED has not been analysed.

The material from the insurance company Agria showed that the numbers of boxers with stifle related problems decreased, but not as much for all other breeds. The number of boxer owners that were paid for their dogs' life insurance due to stifle problems decreased more than for all other breeds.

Since the start of SKC:s health programme there has been a steadily decreasing trend of young Boxer affected with stifle arthrosis. In the statistics from the insurance company Agria the status of the elderly Boxers are more likely to be represented. The decreasing of stifle arthrosis in this material is not that large as for all other breeds.

In the future it is of great importance to the Boxer dogs in Sweden to continue the radiographic screening of stifle joints. Furthermore, one should in the breeding programme only use breeding animals that not are affected with stifle arthrosis and actively evaluate the progenies of these animals regarding the status of the stifle arthrosis.

Introduction

Apart from humans, the dog is the species for which the largest number of genetic disorders is known (Carnier *et al.,* 2004). The dog is considered by many people to be human's best friend. This makes it even more interesting to investigate the problems that influence the welfare of dogs

By the end of the seventies, a discussion started in Sweden about what everybody knew in boxer breeding circles, the boxer often was troubled with problems in the stifle joints. This discussion initiated an investigation in the early eighties including young dogs and puppies. Veterinarian Lars Audell evaluated radiographs of the stifle joints of the young dogs before the age of one year and compared them to radiographs taken when the dogs reached the age of two and three years. The results from this investigation led the Swedish Boxer Club to request boxer dog owners to also include the stifle joint when doing the radiographic screening for hip dysplasia. This voluntary screening made it possible to start a special health program in the Swedish Kennel Club (SKC) for boxers, to include an official evaluation and recording of results from screening of stifle joints (Personal communication, Edgren, 2005).

The aim of this study was to assess the prevalence of stifle arthrosis in Swedish boxers and to investigate the genetic background by estimating the heritability and genetic correlation with hip and elbow status. Another aim was to evaluate if the health programme has made any difference, to study time trends, and to evaluate if the prevalence is associated with age at which evaluation was made, sex of the dog or the clinic, which radiographed the dog.

Theoretical background

Heritability

To predict how much of the phenotypic deviation of an individual that will be transmitted to the offspring we can calculate the heritability (h^2). The heritability is defined as the proportion of the total phenotypic variance that is caused by genetic variance (Griffiths *et al.,* 2005). The heritability for a trait can be described as in Figure 1.

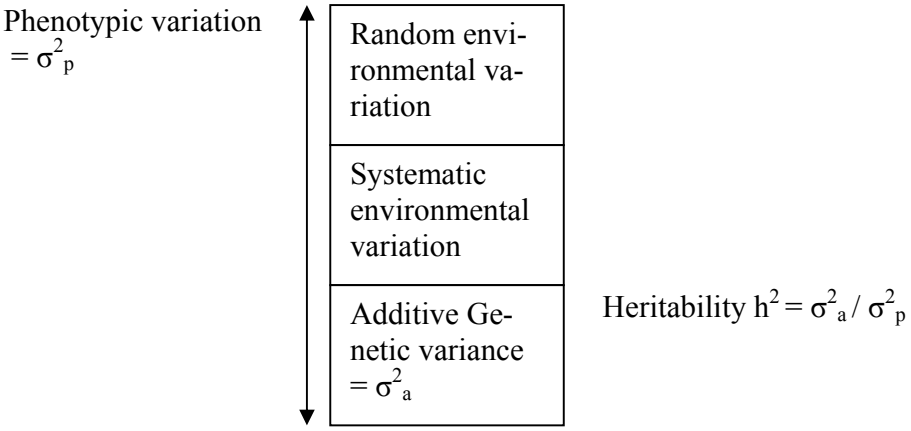

Figure 1. Graphic description of heritability. Adapted from Malmfors (1989).

Apart from genetic variation, the phenotype of a trait is dependent on the environment. Systematic environmental variation is due to known factors, such as sex or litter size. These factors can be adjusted for. Random environmental variation is due to unknown factors. It is of great importance to know what factors that could contribute to the phenotypic variation. The more environmental factors you are able to adjust for, the higher the heritability estimate becomes. Heritability is often categorized as low, medium or high. Fertility is an example of trait with low heritability 0.05-0.15. Osteochondrosis in swine has a medium heritability 0.2-0.3 and withers height has a high heritability 0.4-0.5 (Malmfors, 1989).

If the heritability is low, the phenotype of an animal is a poor indicator of its genotype. To estimate the genetic value of the animal, additional information of the family is an important source. To reduce disease frequency, selection of dogs for breeding is mainly based on exclusion of affected dogs with a disease-related phenotype. If the trait is quantitative or multifactorial, exclusion of affected parents is not necessarily effective or optimal. Strict exclusion of affected parents will have secondary effects such as inbreeding and reduction of the population size (Nielen *et al*, 2001).

Joint anatomy

The synovial joints may be classified based on the shape or form of the articular surfaces such as the plane joint, the ball-and-socket joints (hip-joints), the ellipsoidal joints, and the hinge-joint (stifle-joint and elbow-joint), the condylar joints, the trochoid or the pivot joints, the saddle joints (Miller *et al.*, 1979).

The surface of the hinge joint is shaped like a segment of a cylinder or a cone. This cone or cylinder fits into a corresponding indentation. Strong ligaments on the side stabilize the hinge joint (Sjaastad *et al.,* 2003).

The knee joint or the stifle joint is a complex condylar synovial joint. The stifle joint consists of the femoro-tibial between the rounded condyles of the femur and the more flattened condyles of the tibia. It is connected to the femoro-patellar joint located between the trochlea of the femur and the patella. The two joints are interdependent. The patella is attached firmly to the tibia by a strong ligament. As a result, movement between femur and tibia also causes movement between the patella and the femur (Evans, 1993).

After skeletal maturity the contour of the femoral medial condyle is round. The lateral condyle is smaller and has a more flattened surface on radiographic pictures (Morgan *et al.,* 2000).

The joint surfaces are covered by cartilage that provides the joint with low friction between the separate parts. The stifle joint is stabilized on both sides by one ligament inside (medial collateral) and one outside (lateral collateral). A crucial part for normal stifle function is the insertions for the patellar tendon of the quadriceps of the thigh. The patella is also connected to the front edge of the tibia by the patellar ligament.
Inside the stifle joint in the fossa between the condyles there are two cruciate ligaments, the cranial (lateral) cruciate ligament in the front and the caudal (medial) cruciate ligament in the back of the joint. The caudal cruciate ligament is longer and slightly heavier than the cranial one. These structures contribute to the stability of the stifle joint. (Evans, 1993).

The cruciate ligament crosses each other and the function is to prevent the stifle to slide forward and backwards between the femur and tibia. Between the femur and tibia there are also two meniscuses that provide the stifle joint with shock absorber and also have a friction-inhibited function. The meniscuses also provide stability to the joint (Frykman, 2004). The menisci attaches to the femur and tibia by meniscal ligament. The joint capsule surrounding whole stifle joint is the largest joint capsule in the body (Evans, 1993). The interior part of the capsule consists of a synovial membrane that provides the joint with joint fluid (synovia). The joint fluid lubricates the surfaces inside the joint and decreases friction. The membrane consists of vessels and nerves. Pain in the stifle joints originates from these nerve endings. The joint cartilage does not have vessels or nerves and gets its nourishment mainly from the joint fluid. The external part of the joint capsule structures consists of a more stabile connective tissue that also provides the stifle joint

stability. The joint capsule also has nerves and vessels with many receptors. The whole joint capsule attaches to the skeleton under and above the joint (Frykman, 2004).

Arthrosis

The name Arthrosis comes from the new Latin word *arthro´sis* which in terms comes from the Greek word *a´rthron* which means joint (Nationalencyklopedin, 2005). Arthrosis is a *chronic, degenerative, non-infectious* joint disease. The disease involves the joint cartilage, the joint capsule and the subchondral bone tissue. Arthrosis can be divided into primary and secondary arthrosis, depending on the background. The arthrosis that occurs with ageing must be classified as primary arthrosis. Typical of secondary arthrosis is development of osteophytes and only minor cartilage changes. Secondary arthrosis usually develops as a result of instability caused by traumatic injuries, rupture of ligaments or fractures. As the knowledge of joint disease increases, the number of causes of primary arthrosis decreases (Grøndalen, 1979).

Arthritis is an acute or chronic, infectious or non-infectious, *inflammatory* joint disease that may lead to arthrosis. Osteochondrosis is a non-infectious disturbance of the endochondral ossification process and can cause degeneration of cartilage and bone. It may lead to osteochondritis dissecans, arthritis and arthrosis. Osteochondritis dissecans is a localized osteochondrosis characterized by partial or complete detachment of a fragment of the joint cartilage and a synovial inflammatory reaction and that may lead to arthrosis. The development of arthrosis can only take place in the joint in use. The larger joints, and particularly the limb joints, are the first to show degenerative changes. A reaction to joint instability is the formation of osteophytes (Grøndalen, 1979).

A loss of the anterior (cranial) cruciate ligament in dogs causes large periarticular osteophytes in the stifle joint as a sign of instability. Changes in joint cartilage were small and not correlated to instability and the size of osteophytes (Olsson *et al.,* 1972).

The anterior (cranial) cruciate ligament is more important than the posterior (caudal) cruciate ligament for the stability of the stifle joint. (Pournaras *et al.*, 1983).

In studies made on dogs by Paatsama and Sittnikow (1972) the anterior cruciate ligament of the stifle joint was cut of. Radiological osteophytes like formations were found as early as three weeks after the operation in the femoral joint surface of the femoro-patellar joint and on the femoral condyles of the femoro-tibial joint and on the distal end of the patella.

Stifle Arthrosis in Boxer dogs

Most dogs with stifle arthrosis have difficulties sitting down properly and tend to sit on their thighs and have clinical symptoms of pain and lameness. Often the dogs have problems getting up and have a rigid appearance, especially in the morning. During the early eighties the development of the stifle joint was studied clinically and radiographically in 24 unrelated young Boxer dogs before the age of one year by veterinarian Lars Audell. Re-examinations were made when the dogs were 2 and 3 years of age. In the first study Audell found variation in the development of the proximal part of the trochlea of the distal femur and in the bone surrounding the intercondyloid fossa (Figure 2). Radiographic evidence of abnormal development in these regions in the young dogs resulted in a high frequency of periarticula osteophyte formations in the stifle joint at 2 and 3 years of age. Audell suggested that faulty development of the distal femur is one of the major causes of stifle arthrosis in the Boxer breed. As a result of these investigations a screening programme organised by the Swedish Kennel Club was initiated (Audell, 1990).

The official evaluation of the radiographs of the stifle joints mainly evaluates the occurrence of periarticular osteophytes (Figure 3). These are mainly found on both lateral and medial sides of the trochlea, proximal and distal on the patella and on medial and lateral tibial plateau. Bilateral lesions are most common. Audell suggested that a majority of stifle arthrosis in Boxer dogs usually is a faulty development of the distal femur and that cruciate ligament rupture which are frequently seen in Boxer dogs usually are secondary to the arthrosis. This has not yet been scientifically proved (Personal communication, Audell, 2005).

Heritability estimates have previously been estimated for stifle related problems in Boxers in the Netherlands. Severe stifle problems had a medium-high heritability (≥ 0.20) with little impact from litter effects and risk factors. This high heritability estimate gives good prospects for changes through genetic selection (Nielen *et al.*, 2001). Earlier studies of instability of stifle joints in dogs showed that instability causes osteophytes (Olsson *et al.*, 1972).

Another osteophyte development disease that affects the Boxer breed is spondylosis deformans. A study made on Italian Boxer dogs showed that spondylosis deformans is a very usual skeletal disease in the Italian Boxer population. The heritability estimates were 0.25-0.48. A breeding programme to decrease the incidence of spondylosis deformans was found to be urgent (Carnier *et al.*, 2004).

Figure 2. Radiograph of a stifle joint of a young boxer dog with development changes of the distal part of femur.

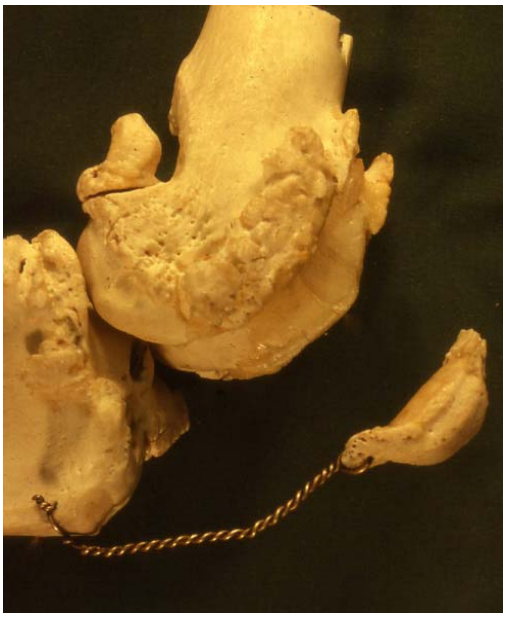

Figure 3. A stifle joint with osteophytes.

SKC:s health programme

In response to requests from the Swedish Boxer Club, an official screening by the SKC started in 1989-01-01. A rule that the stifle joint status has to be known for both sire and dam if the progeny are to be registered by the SKC was initiated in 1997-01-01 (RAS, 2004). From 2006-01-01, all progenies after parents that are affected with stifle arthros are not accepted for breeding (Personal communication, Edgren, 2006).

To get an official examinations and evaluation of the stifle with radiological screening, the dog has to be older than 12 months. The result is evaluated and recorded by the SKC. The goals for the health programme are to increase the number of radiographed dogs to 70% and to keep the number of affected beneath 10%. Furthermore, a goal is to decrease the number of dogs with stifle lesion later in life. To achieve the goals of this health programme the Swedish Boxer Club will provide information to breeders and male dog owners and provide information about selection in family groups, and also only use breeding animals without stifle arthrosis (RAS, 2004).

Material and methods

Computerized records of stifle arthrosis, hip dysplasia (HD) elbow dysplasia (ED) status and pedigree information of Boxer dogs where received from the SKC. Boxers born between 1983 and 2004 and examined from 1989 until May 2005 were included in the study. If a dog had several records for any of the defects, only the latest record was included in the analyses. The material consisted of 3990 records of stifle examinations, 1890 male dogs and 2100 female dogs. The number of HD records was 4197 and the number of ED records was 390. The data included information on dog identification, dates of birth and of x-ray screening, sex and x-raying clinic. The age of dogs at x-ray assay ranged from 11 to 66 month. A score for stifle arthrosis was attributed using a four-grade system: grade 1 = no osteophytes, 2 = mild osteophytes, 3 = moderate osteophytes and 4 = substantial osteophytes. The classification for hip dysplasia was attributed using a four-grade system, grade 1 = No sign of hip dysplasia or Near normal hip joint, 2 = Mild hip dysplasia, 3 = Moderate hip dysplasia and 4 = Severe hip dysplasia. The pedigree data were obtained from the pedigree register of the Swedish Boxer dog population from SKC, resulting in 26 943 dogs in the analysis. Too few dogs were screened for ED for a genetic analysis to be possible.

The material from the insurance company Agria consisted of all incidences of diseases and injuries that Boxer owners have used their insurances, both for veterinary care and life insurance between 1995 and 2003. These materials were compared to all other breeds put together. In this study only the lesion that can be connected to the diagnosis of stifle arthrosis were used.

Statistical methods

Statistical analyses were performed with the computerized statistical programs SAS (2001) and DMU (Madsen & Jensen, 2000). Analysis of variance with Proc GLM (SAS) was used to analyse the effect of systematic environmental factors on stifle arthrosis and HD. The effects of sex, test year, age and clinic were included in both models.

The model used for stifle arthrosis was:

$$y_{ijk} = \mu + s_i + m_j + c_k + e_{ijk} \quad (1)$$

where:

y = grade of stifle arthrosis
μ = total mean value
s_i = fixed effect of sex (i = male, female)
m_j = fixed effect of age in months (j = ≤12, 13, …24, 25-26,…35-36, 37-40, 41-44, 45-48, >48, all dogs missing information on age were collected in a dummy class)
c_k = fixed effect of clinic (k = 1.. 199, dogs with unknown clinic were collected in a dummy class and if there were just one examination per clinic the results were collected in one dummy clinic)
e_{ijk} = residual (~ND (0, σ^2_e))

The model used for hip dysplasia (HD) was:

$$y_{ijk} = \mu + m_j + c_k + yr_l + e_{jkl} \quad (2)$$

where:

y = grade of hip dysplasia
μ = total mean value
m_j = fix effect of age in month (j = ≤12, 13, …24, 25-26,…35-36, 37-40, 41-44, 45-48, >48, all missing data were collected in a dummy month)
c_k = fix effect of clinic (k = 1.. 217, unknown clinics results were collected in a dummy clinic and if there were just one examination per clinic the results were collected in one dummy clinic)
yr_i = fix effect of test year (j = ≤1992, 1993, 1994…..2005, missing data on test year was collected in a dummy class).

The effect of test year was not significant for stifle arthrosis, and correspondingly, sex was not significant for HD. To estimate the heritability of stifle arthrosis and hip dysplasia the statistical program DMU was used. In this genetic analysis, models (1) and (2) were used in a bivariate analysis, with the added effect of the animal's breeding value (~ND (0, $A\sigma^2_a$), where A is the relationship matrix, and σ^2_a is the additive genetic variance.

Results

During the last fifteen years the number of Boxers registered in the SKC has been stable. Around 550 dogs are registered each year (Figure 4) (Hundsport, 1999 and 2005).

Since 1989 and the introduction of the health programme, the stifle joint are included and are officially scored by the SKC. Today almost all Boxers have their stifle joints evaluated and the results are registered in SKC database. The number of Boxers that are radiographed today is increasing and in 2004 approximately 67 % of the Boxers registered were radiographed (Figure 5).

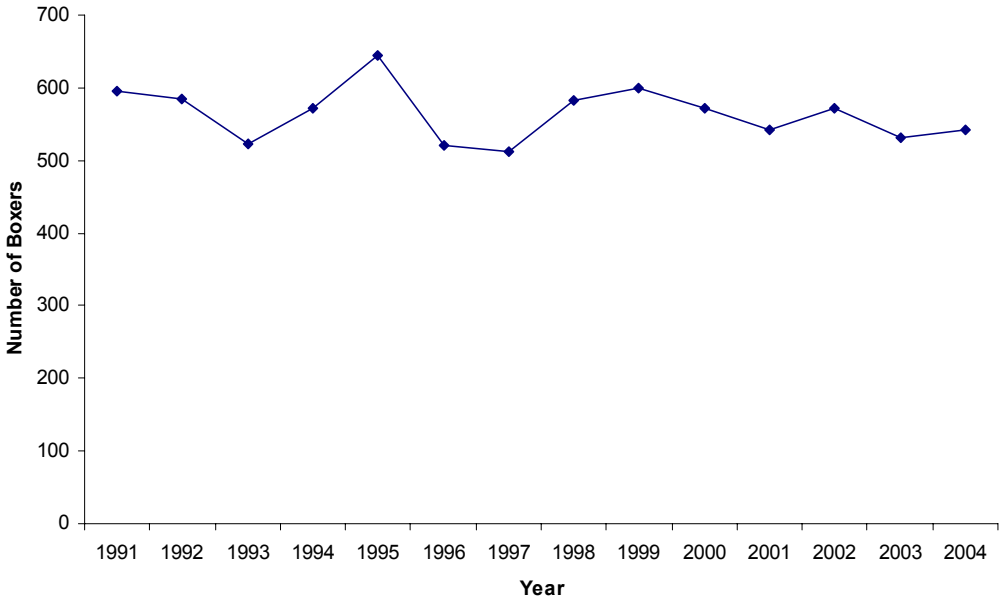

Figure 4. Number of Boxers registered in the Swedish Kennel Club between the years 1991 and 2004.

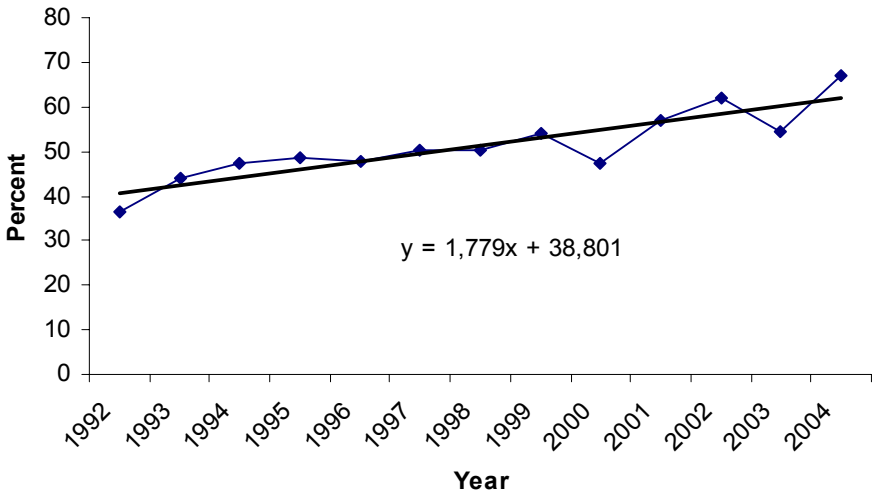

Figure 5. Percentage of radiographed Boxers per year.

The proportion of Boxers with stifle arthrosis has decreased since 1992. The percent of Boxers with stifle arthrosis in 1992 was 17.1% and the percent in 2005 (until May) was 6.25% (Figure 6). The mean in age of all radiological screened Boxer dogs is almost 16 month. The mean of the screened and affected dogs is 19 month. The mean in age of all screened dogs and the affected dogs per test year is present in Figure 7.

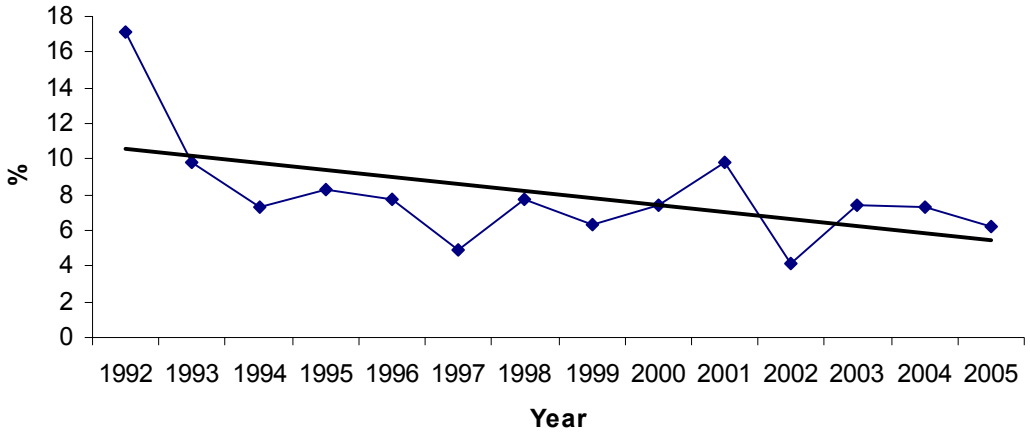

Figure 6. Percent of Boxers with stifle arthrosis in Sweden per test year.

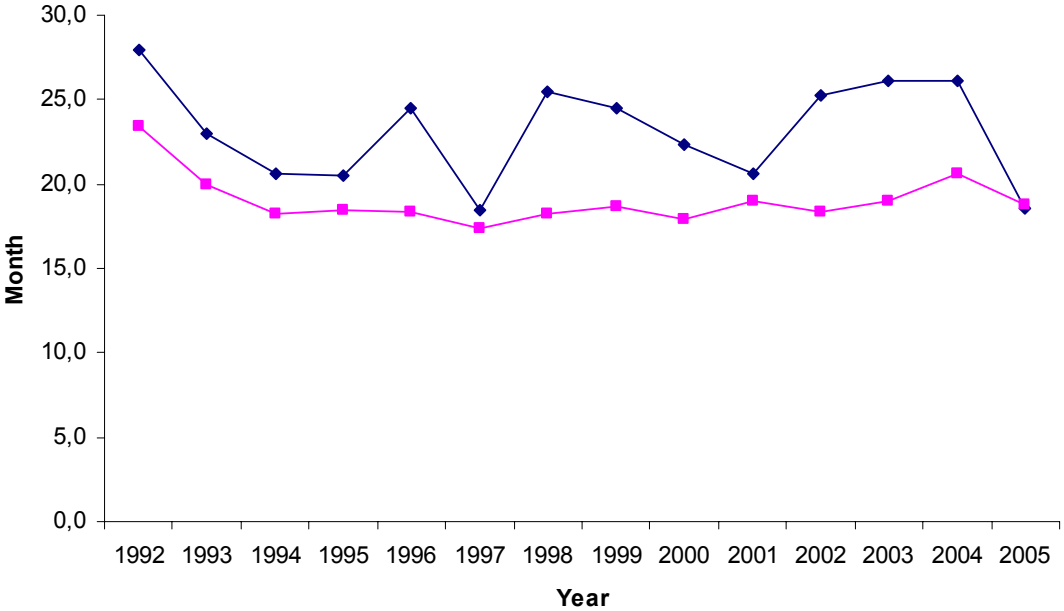

Figure 7. Mean of age in months of the screened dogs per test year. The affected dogs in the top line and all dogs in the lower line.

Genetic analysis

The GLM procedure in SAS (2001) for stifle arthrosis showed significant ($p<0.0001$) differences for the effect of sex. Male dogs were significantly more affected than female dogs. The effect of age of dogs at x-ray showed a significant increase of stifle arthrosis ($p<0.0001$) but not quite significant for hip dysplasia ($p=0.0874$). The effect of test year when the dogs were x-rayed showed a significant ($p<0.0001$) effect on hip dysplasia. The effect of clinic was significant for both traits ($p<0.0001$). There was no significance for the effect of test year in stifle arthrosis and no significance for the effect of sex in hip dysplasia.

The heritability estimates were 0.11 (SE 0.04) for stifle arthrosis and 0.28 (SE 0.03) for hip dysplasia (Table 1). The genetic correlation between stifle arthrosis and hipdysplasia was not statistically different from zero (0.0087 ± 0.14).

Table 1. Estimates of heritability ± SE, genetic and residual variance.

Trait	**h^2 ± SE**	**σ^2_a**	**σ^2_e**
Stifle arthrosis	0.11 ± 0.04	0.01	0.09
Hip dysplasia	0.28 ± 0.03	0.07	0.19

Records from the insurance company Agria

The data shows insured Boxers in Sweden compared to all other insured dog breeds. Boxers have considerably more stifle related problems than all other breeds put together. A comparison was done of how frequently owners to insured Boxer dog have their dogs treated by veterinarians or get their life insurance paid due to stifle lesion or problems, compared with all other insured dogs. The numbers per 10 000 of Boxer dogs with stifle related lesion paid by the insurance company is more than two times higher than the total of all other insured dog breeds put together (Figure 8) (Ahlén. 2005).

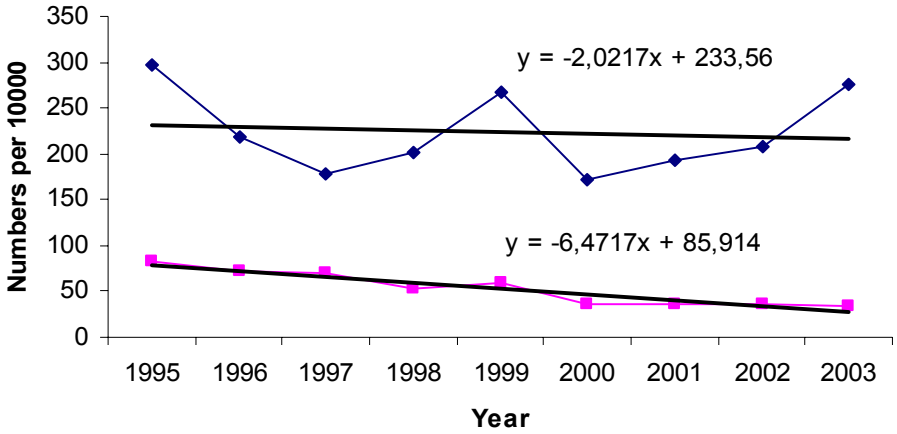

Figure 8. Number per 10 000 Boxers (the top line) with stifle problems compared to all other insured dog breeds (the lowest line) put together from the insurance company Agria.

A comparison of how frequently veterinarians treat insured Boxers due to stifle lesion and stifle problems compared to all other insured dog breeds is shown in Figure 9. The numbers are decreasing but the total of all other insured dog breeds are decreasing much more (Ahlén, 2005).

A comparison how frequently insured Boxer dog owners get their dogs life insurance paid due to stifle lesion or stifle problems compared to all other insured dog breeds is shown in Figure 10. The numbers are decreasing more than the total of all other dog breeds put together (Ahlén, 2005).

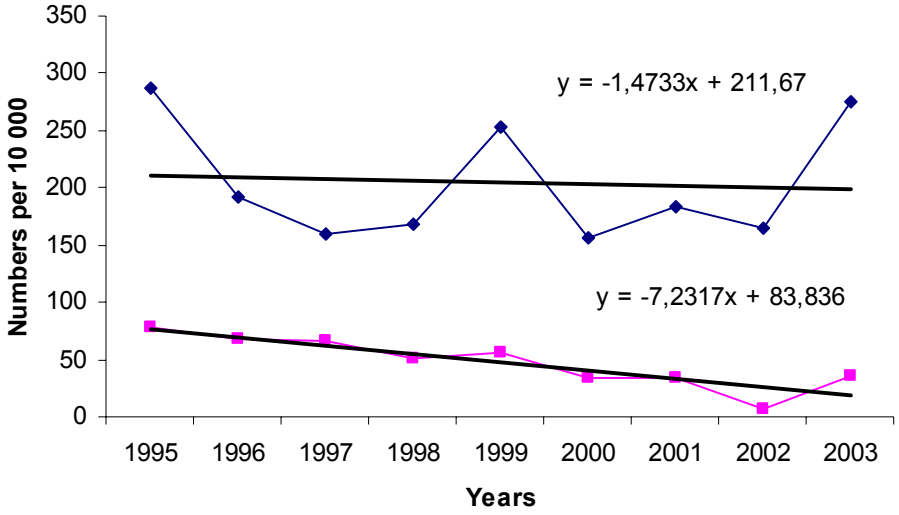

Figure 9. Number per 10 000 Boxers (the top line) with stifle problems treated by Veterinarian compared to all other insured dog breeds (the lowest line) put together in the insurance company Agria.

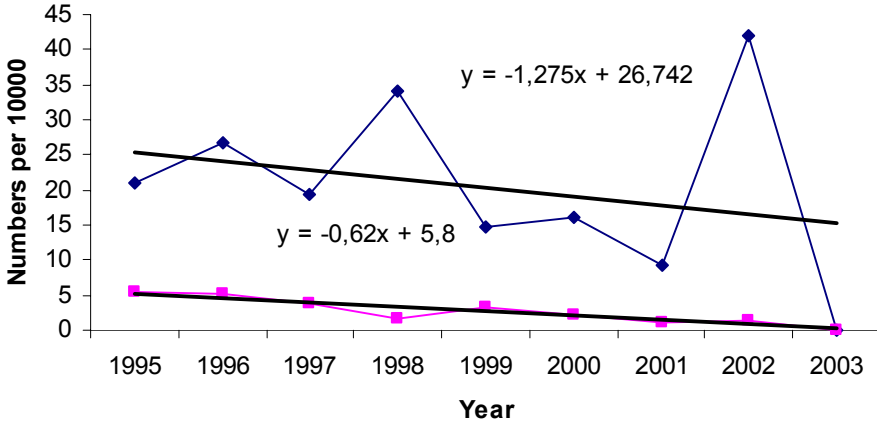

Figure 10. Number per 10 000 Boxers (the top line) owners get paid for their dogs life insurance due to stifle problems compared to other insured dog breeds (the lowest line) put together in the insurance company Agria.

Discussion

Stifle arthrosis is a quantitative trait and are influenced by many factors. There is no question that arthrosis in humans cause a lot of pain. The problems for dogs can be expected to be at least as painful as for humans. It is important to distinguish between the secondary arthrosis in young dogs and the primary arthrosis that arises during aging. The development of arthrosis that in some cases can arise during aging is a response to skeletal wear of the body. One effort the Boxer breeders are dealing with is to decrease the developing of arthrosis in the stifle joint of young Boxer dogs.

The number of Boxers with stifle arthrosis has shown a steadily decreasing trend during the last years. In this material the first evaluation in 1992 the percentage was as high as 18%. This seems extremely high, especially considering that the next year the level was at around 10%. The high level in 1992 may be due to non-random sampling, e.g., if mainly affected dogs were radiographed in the beginning. It can also be seen that dogs were older in 1992 than later (Figure 7). Regardless of that year, the level has steadily decreased to almost 6%. Simultaneously the percentage of radiographed dogs has increased from 37 % in 1992 to 67 % in 2004. It cannot be totally excluded that the sampling of dogs has gone from mainly screening affected dogs or dogs at risk to a more random sampling (just by virtue of sampling a much larger proportion of the population), which would result in an apparent downward trend in arthrosis. On the other hand, it is not easy to see how such a non-random screening could come about, especially not after 1997 when screening of parents was mandatory for registration of puppies.

The health programme for Swedish Boxer dogs has a goal of 70 % radiographed dogs and this is almost reached. Another goal is to keep the number of defected beneath 10%: this is reached, because the prevalence in 2005 was 6.25%.

The heritability estimate for stifle arthrosis in this study was low (0.11). This supports the theory that there are many other reasons for stifle arthrosis besides genetics. There are problems to have an accurate diagnosis before the osteophytes are visible on radiograph. In this study the heritability estimate for hip dysplasia (0.28) was higher than for stifle arthrosis. This heritability estimate is somewhat lower than that found for other breeds in Sweden (Swenson *et al.*, 1997a; Malm, 2005). The genetic correlation between hipdysplasia and stifle arthrosis was not different from zero. This indicates that both traits have to be considered in the breeding programme. The material showed an increasing number of affected dogs with age, which indicates that a new screening of the breeding animal later in life might show a more accurate picture of the status for the breeding animal and perhaps detain the development of stifle arthrosis in young dogs. It is also important to evaluate the family of the breeding animal to decrease the risk of stifle arthrosis. The systematically environmental factors such as litter size, age of the mother of the litter, feeding and exercise are much harder to compare between dogs and this factors may also contribute to the prevalence of stifle arthrosis.

In the statistics from Agria covering the years 1995 to 2003 the number of Boxers with stifle problems had decreased but not as much as for all other dog breeds during the same

period. The most probable cause for this might be the age of the dogs when they begin to develop problems doe to stifle arthrosis. Most dogs with stifle arthrosis at the age of one year do not have so severe problems that they need veterinary care but might need it later in life. When veterinary care and life insurance were separated, the number of Boxer owners that were paid due to their dog's life insurance for stifle joint problems had decreased more than for dogs of other breeds. The knowledge of stifle arthrosis in the Boxer breed has increased since the beginning of the heath programme. The breeders have to use breeding animals that are not affected. The increasing skill of the veterinarians makes treatment more available and effective. The reason can also be that the diagnoses might differ over time. In Agria statistics the age of the dogs is not known and it might be the older dogs that are affected. In the SKC-data, the mean of the affected dogs was higher than the mean of all screened dogs (Figure 7). If the dogs were examined at the age of one year and had no remark, and then for some reason is examined again, the latest evaluation is the one in the study. The examination at the age when most of the dogs are radiographed does not expose the whole truth. On the other hand, it is important with an early diagnosis in order not to use an affected animal in breeding.

Often we hear associations of obesity and joint problems. Obesity is a common problem for many dogs. Especially during the growth period, the skeleton maturity is crucial and it is important that the dogs are not fed too much energy. The amount of calcium is also important (Personal communication, Hedhammar, 2006). In this study the effects of arthrosis connected to obesity or nutrition was not paid any attention. But generally dogs with weight problems have much heavier body and put much more stress on the body and legs.

Within the group of skeletal disorders, hip and elbow dysplasia have been investigated the most. In previous genetic studies of hip dysplasia and elbow dysplasia in other breeds, the heritabilities were found to be medium or high (Swenson *et al.,* 1997a,b). The prevalence of hip dysplasia was found to be significantly higher in female dogs than in male dogs for German Shepherd, Golden Retriever and Saint Bernard (Swenson *et al.,* 1997a). The prevalence of elbow dysplasia in Bernese Mountain Dog was found to be slightly lower in male dogs than in female dogs. However, the opposite was found for Rottweiler (Swenson *et al.,* 1997b). Genetic aspects of other skeletal diseases like Spondylosis deformans have been studied less. Spondylosis is another arthrosis related problem in Boxers. The estimated heritability from multivariate analysis of spondylosis in Italian Boxer population ranged from 0.25 to 0.48. (Carnier *et al.,* 2004).

In Norway the Kennel Club screen their Boxer dogs for spondylosis and not stifle arthrosis. It would be very interesting to match these two diseases and investigate if there is any genetic correlation between spondylosis and stifle arthrosis.

It is desirable to decrease the incidence and severity of stifle arthrosis for enhancing longevity and welfare of dogs It would also be desirable to determine early if a dog is at risk of being affected by stifle arthrosis before the disease is visible in radiographic pictures.

The result from this study support the hypothesis that genetic effects are involved and affects the occurrence of stifle arthrosis in Swedish Boxer dogs. The heritability estimates are low for stifle arthrosis but the trait should nevertheless be accounted for in the breeding programme.

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