GRANSKAD ARTIKEL

EVALUATION OF THE PENNSYLVANIA HIP IMPROVEMENT PROGRAM

En litteraturstudie för specialistexamen i hundens och kattens sjukdomar skriven och granskad på engelska och publiceras därför på engelska.

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Canine hip dysplasia (CHD) is a developmental orthopedic disease of the coxofemoral joint causing a painful degenerative joint disease (DJD). Joint laxity is the first observable radiographic sign of CHD, and is often diagnosed radiographically with the hip-extended (HE) view. Internationally there are three different grading systems using the HE radiographic view to assess the severity of CHD. The results are used for genetic control programs in several breeds to improve the health of hip joints. Despite extensive screening of hip status, the prevalence of dysplastic dogs is still high. The Pennsylvania hip screening program (PennHIP) is a radiographic screening method that evaluates three separate radiographs; the distraction view, the compression view and the HE view. This literature study concludes that the PennHIP DI phenotype has a potentially higher heritability than the HE radiographic phenotype alone, and could therefore improve breeding for healthier hip joints.

Canine hip dysplasia (CHD) is one of the most common orthopedic diseases among larger breeds. Hip dysplasia was first described in dogs in 1937 by Schnelle (8, 23). It is a development disease of the coxofemoral joints with an imbalance between the forces on the joint and the associated muscle mass. Hip joint laxity is considered the primary factor causing hip dysplasia (8, 20, 21, 26). This leads to joint instability and incongruity and finally degenerative joint disease (DJD) (4).

The clinical signs of CHD include unilateral or bilateral lameness of the hind limb with abnormal gait, difficult rising after rest, reluctance to exercise, pain and atrophy of the hind limbs muscles (37). Diagnosis is often suspected based on history, clinical examination and hip palpation. The radiographic evidence of hip joint subluxation and DJD are the principal factors that leads to a radiographic diagnose of CHD (26). The first observable radiographic evidence of CHD is hip laxity (8, 20, 21).

There are several international organizations with radiographic screening systems quantifying CHD with the ventrodorsal HE radiographic view, e.g. the Orthopedic Foundation for Animals (OFA) and the British Veterinary Association/The Kennel Club and Fédération Cynologique Internationale (FCI). The severity of CHD is assessed by the degree of subluxation, presence and severity of secondary osteoarthritis (OA) (5).

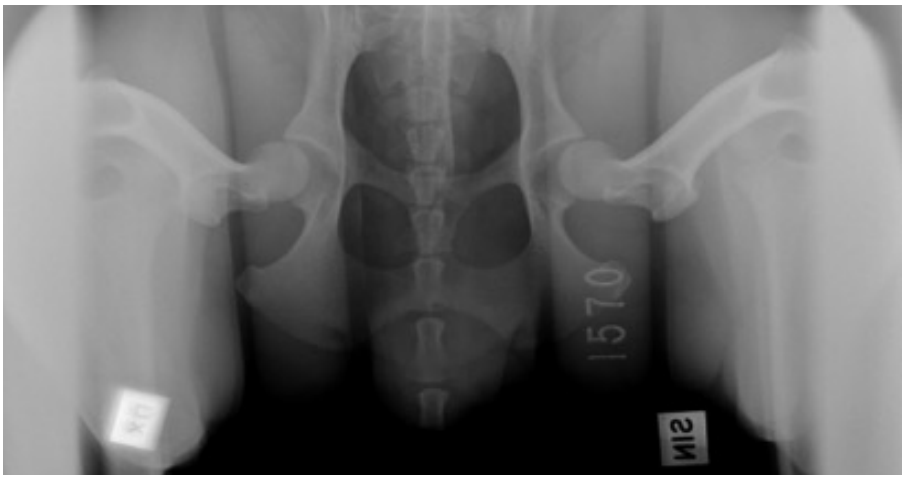

FIGURE 1.

In 1993 the PennHIP was introduced to measure and interpret hip joint laxity. The PennHIP is a radiographic screening method that evaluates three separate radiographs. This includes not only the ventrodorsal HE view, but also the distraction view and the compression view. The distraction view and compression view are used to measure joint laxity and congruity, whereas the HE view gives an additional information about the presence of OA (2).

In Sweden there are about 817 000 dogs (Swedish Central Bureau of Statistic, 2015), approximately 70 % are pure breeds and registered in the Swedish kennel club (SKC). A screening program for CHD was implemented over 35 years ago evaluating the hip status by radiographic examination in young adult dogs. Since year 2000 the

SKC adapted the FCI scoring system as a standard method to evaluate the hip status in dogs. The prevalence of hip dysplasia is still high, and the screening program to reduce the prevalence of CHD has been variable despite open registers with public access to pedigree records (17).

As the prevalence of CHD is still high, the radiographic method which best measures the laxity in the hip joint and distinguishes dogs susceptible to DJD from those who are not is of great interest. Therefore the aim of this literature study is to evaluate and compare the PennHIP method with the traditional ventrodorsal HE radiographs in order to determine if the PennHIP could be of use in order to decrease the prevalence of CHD in dogs.

Pathogenesis of CHD

CHD is a polygenic disease with a complex inheritance and a multifactorial disorder meaning that several genes and environmental factors impact the incidence and the severity of the disease (4, 8, 24, 26, 29). Factors that predispose genetically susceptible individuals to develop CHD are; abnormalities of the pelvic muscle mass (3), various hormones including estrogen and relaxin that may contribute to relaxation of the pelvic and coxofemoral ligaments (1, 8, 34), extra caloric intake and weight gain increase the prevalence of CHD (14, 20, 29, 31).

Anatomy, physiology and pathophysiology

The coxofemoral joint is a spheroid joint stabilized by its joint capsule, ligaments and surrounding pelvic muscles (15). When laxity of the joint is increased, the surrounding structures fail to restrain the femoral head within the acetabulum causing a subluxation. The abnormality in the joint finally leads to OA (8, 20).

In a healthy hip joint, the weight bearing forces are distributed across the entire cartilage surface of the acetabulum and during weight bearing, the trans-articular musculature produces a large force that tends to reduce the movement and stabilize the femur into the acetabulum space (37). In the canine subluxated hip, the femoral head shifts laterally during weight-bearing and the trans-articular muscle force must increase to compensate for the lateralization. The weight bearing forces are limited to the dorsal labrum of the acetabulum which causes cartilage stress. The increase in cartilage stress causes cartilage damage, joint inflammation and OA. In dogs younger than 6 months the subluxation causes microfractures and remodelling of the pelvic joint surface. In older dogs the inflammation cause changes in the joint shape due to new production of bone and/or resorption (20).

Screening methods

Radiographic analysis of the hip joint to detect CHD has been used since first described by Schnelle in 1937 (8, 20). Worldwide there are three different grading methods used for radiographic assessment of CHD. In the United States and Canada, the Orthopedic Foundation for Animals (OFA) uses a seven-point grading system to evaluate CHD. In the United Kingdom, Ireland, Australia and New Zealand, the British Veterinary Association /Kennel Club (BVA/KC) uses a hip scoring scheme from 0-6 where 0 is the ideal. In the rest of Europe, Asia, Russia and parts of South America the Fédération Cynologique Internationale (FCI) scoring system is used (5).

Fédération Cynologique Internationale

The FCI screening for CHD has been used for over 40 years. The radiographs are scored by specialized veterinarians approved by the national kennel club or breed club of which the dog is registered. The scoring system combines the HE radiographic evaluation with the Norberg Angle (NA) measurement. To optimize the scoring, a frog-leg position (abducted stifles) can be used (5, 39). The scoring system gives five different scores from A to E. A and B correspond to non-dysplastic hips and C, D and E represent mild, moderate and severe hip dysplasia. The minimum age for screening is one year for most breeds and 18 months for large and giant breeds. Individual breeding clubs decide whether dogs with CHD may be used in further breeding, meaning that dogs with dysplasia can be used in breeding programs (5).

Ventrodorsal hip-extended radiograph

The most used radiographic method to evaluate evidence of subluxation or OA is the ventrodorsal HE view (5). The dog is sedated and placed in a dorsal recumbency with the hind limbs pulled into extension, the femurs parallel, and pronated to center the patella over the trochlear grove (37). The grade of hip joint dysplasia is based on the degree of subluxation, the amplitude of NA, the shape and depth of the acetabulum, and signs of OA (5).

The NA is used to determine the subluxation of the femoral head from the acetabulum. The NA is calculated by lines that intersect the center of the femoral head. The first line is connecting the center of each femoral head, and the other line is drawn from the center of the femoral head to the craniodorsal acetabular rim (figure 1). An NA less than 105° is considered an abnormal hip joint and an indication of dysplasia (5).

Passive and functional hip laxity

Hip laxity has been showed to be the main cause of canine hip dysplasia (8, 20, 26). In 1990 Smith et al (26) introduced the concept of passive versus functional hip laxity to distinguish between subluxation seen radiologically compared to subluxation during weight bearing. They performed postmortem dissection of hip joints to examine the anatomic and functional bases of coxofemoral stability. The aforementioned authors suggested that the joint capsule, round ligament of the femoral head and the hydrostatic stability factors are the passive constraints that maintain the congruency between the femoral head and acetabulum without active muscles and weight bearing (26). If these structures fail to limit the lateral displacement of the femoral head in the relaxed dog, it is called passive laxity. The functional

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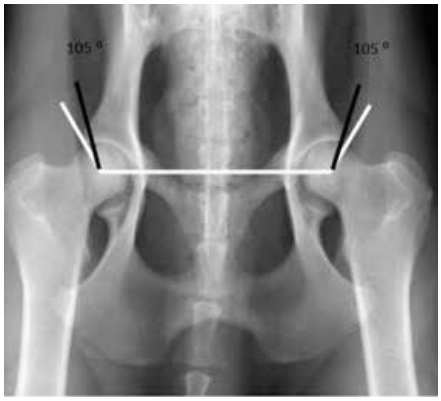
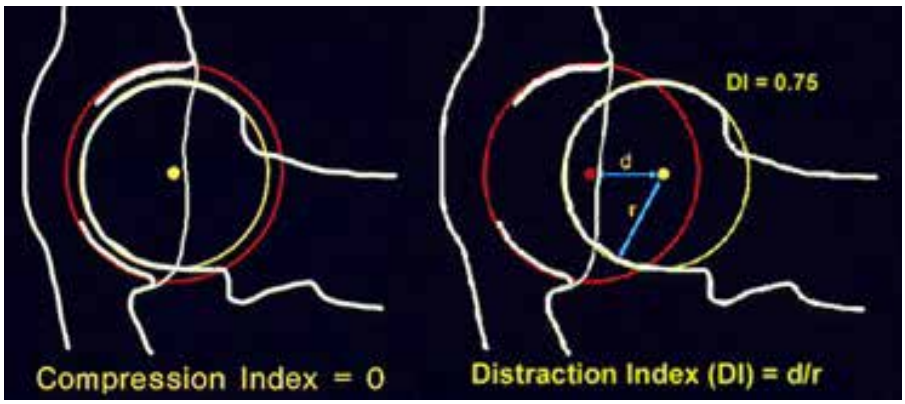


FIGUR 2.



FIGUR 3.

laxity is when the femoral head moves laterally during weight bearing and is the pathological form of hip laxity. Maximal lateral displacement occurs with the hip in a standing natural position (10, 26). Passive laxity is a pre-requisite for functional laxity to cause OA but is not sufficient alone to cause OA. Functional hip laxity during weight bearing is of great diagnostic interest, but currently there are no diagnostic method measuring it (26). Passive laxity can be measured and has been reported to be of interest as it has shown to be highly correlated with the development of OA and the clinical sign of hip dysplasia (22, 26, 32).

Pennsylvania Hip Improvement Program

Studies of passive joint laxity (10, 26, 27) developed the University of Pennsylvania Hip Improvement Program which was introduced as a hip screening method to explore the passive hip laxity and development of DJD in 1993 (24). The PennHIP program focuses mainly on passive joint laxity of the coxofemoral joint (39).

Initially the method combined two radiographic views with the dog in a dorsal recumbency, one compression view with the femoral head fully seated in the acetabulum, and a distraction view where the femoral head is at its maximum lateral position. To quantify the level of joint laxity a distraction measurement index method was created (26). In order to quantify the degree of passive laxity a radiolucent fulcrum is used to cause femoral head subluxation. The device is placed between the thighs and the femurs are pushed together distally and a distraction radiographic view is taken (10, 26). The PennHIP method of hip evaluations requires the dog to be heavy sedated or anesthetized and positioned in a dorsal recumbency (26). To detect hip laxity, the dog can be as young as 16 weeks (25, 26, 27, 32) but the recommended age for screening is 6 months or older (39). The PennHIP method consists of three different radiographic exposures: a ventrodorsal HE radiograph where the femurs are held in a 10°-15° extension, a compression radiograph measuring a compression index (CI) and a distraction radiograph with the legs in a vertical natural position and the hips distracted (measuring the distraction index, (DI)). The distraction device is placed between the legs at the level of proximal femur. This device abducts the femoral head for a maximum lateral displacement (10, 26). The linear distance between the center of the acetabulum and the center of the femoral head on the distracted radiographic view (d) is divided by the radius (r) of the femoral head to achieve a unite-less measure of laxity (DI) (Figure 2) (2). The HE view is used to assess the presence or absence of OA based on the OFA type criteria, and the compression view is used to evaluate the congruency of the coxofemoral joint (10). Only PennHIP certified veterinarians and technicians can officially perform the PennHIP procedure and enroll the radiographs into the PennHIP Analysis Center for evaluation (2, 39). After the radiographs have been reviewed, information about the DI of each hip and the grade of DJD relative to other members of its breed, a hip evaluation report is mailed to both the owner and the veterinarian.

The PennHIP is not a fail/pass system, it's a continuous scale that reports the DI for each hip with an assessment of the presence and severity of OA and a laxity ranking compared with dogs within the same breed. However, dogs with definitive diagnosis of OA have a "confirmed hip dysplasia" status (2, 22).

The DI ranges from 0 to >1, where 0 represents full congruency of the hip joint and 1 represents full luxation (2, 22, 39). Dogs with a DI of <0,30 are considered less susceptible to develop DJD. For example Borzois and Greyhounds have an extremely low prevalence of CHD (27), whereas a DI of ≥0,70 is very likely to develop OA (16). The risk of developing DJD later in life increase with increasing DI. It has been showed that every 0,1 rise in DI is associated with an 2,2-4,1-fold increased probability of developing DJD by the end of life (29, 32). Approximately more than 50% of dogs with a DI between 0,3-0,7 develop DJD (19, 26, 32).

The DI varies between breeds, but for individuals the DI remains constant from 16 weeks of age (25, 27, 32). Tightening of the hip due to OA has not been showed, the DI remains unchanged (7, 27).

Discussion

CHD is one of the most common orthopedic diseases in dogs causing discomfort such as pain, lameness and gait alterations (37). The incidence varies greatly between breeds but can be as high as 80 % according to the OFA statistics from 2014 (18). The phenotypic manifestation in dog is DJD but the expression may not be radiographically evident until later in life (14, 29, 31).

Radiographic evidence of hip joint laxity or signs of OA are the principal factors that lead to a diagnosis of CHD (26). Joint laxity early in life has been showed to increase the risk of developing CHD (8, 20, 26, 30).

A reliable screening test paired with the phenotype with high heritability is of great interest for a successful genetic control CHD (26, 32). The test that can provide the most reliable difference between dogs susceptible and non-susceptible to DJD can increase the selection pressure and more rapidly cause a genetic change for healthier hip joint formation.

Since 2000, the Swedish Kennel club uses the FCI protocol to evaluate the hip status in an open register, however, radiographic screening programs for CHD was implemented over 30 years ago. The ventrodorsal HE radiographic view with calculation of NA has been the radiographic screening choice for evaluating CHD. The results are used for genetic control programs for several breeds to improve the health of hip joints where only dogs with normal health status are accepted for breeding (17). The open registration for hip status and scoring may have improved the medial score for CHD in several breeds (9, 36). One study (11) analyzed 760,455 hip scores from the OFA database across 74 breeds between 1970 -2009. The study found a genetic improvement of CHD suggesting that the OFA system has been effective reducing the number of severely affected dogs, although limited progress has been made reducing the overall status of CHD (11). Despite the extensive screening of hip status, the prevalence of radiographic dysplastic dogs is still high. The improvement of CHD has been disappointing in Sweden (17).

Worldwide, the ventrodorsal HE stress radiography is used for hip joint screening. Although several authors question the reliability and usefulness of using this method as scientific evidence (19, 26, 38).

Biochemical studies have revealed that passive hip joint laxity is minimized in the ventrodorsal HE stress radiograph as the femoral head is pushed into the acetabulum causing the joint capsule and ligaments of the femoral head to twist which tightens the seating and falsely lowers the extent of the subluxation (26, 28). One study (38) reported that different radiologists scored the same hip joints very differently. This question whether the FCI screening method should be used for evaluating CHD. Also, if the patient is incompletely anesthetized or sedated, the dog will respond to the hip extension by contracting the pelvic muscles and thereby improving the seating of the femoral head in the acetabulum and falsely lowering the extent of subluxation (26). Another major concern is that hip phenotype can change from normal to abnormal after 2 years of age. Early diagnosis of CHD is therefore of great interest to prevent affected animals to be used in breeding programs (14, 31). The OFA, BSA/KC and FCIs systems evaluate hip status in dogs less than 24 months of age and therefore several false negative dogs that later in life develop CHD might have been selected for breeding. Some authors suggest that dogs selected for breeding should have radiographic hip evaluations regularly through life (31).

Several studies have compared radiographic measurements of CHD and have shown the high sensitivity of DI for detecting passive hip joint laxity relative to other radiographic methods (12, 19, 26, 30, 32) and to predict the onset and degree of OA (22, 26, 32). There are also studies that have revealed a breed-specific relationship between DI and the risk of DJD (27, 30, 32). Smith et al 2001 (30) calculated the risk of developing DJD by using a logistic regression model and concluded that DI was a significant risk factor. They suggest that the DI rate is breed specific, e.g. for a German Shepherd dog ≥ 24 months old, each 0,1 raise in DI is associated with a 2,7-fold increase in the probability of having DJD, where a Rottweiler has a 1,9-fold risk. Interestingly the German Shepherd dogs seem to be less tolerant of passive hip joint laxity despite a lower mean value of DI (0,41) compared to Rottweilers with a DI at 0,5 (30). It is hypothesized that the German Shepherds hind limb conformation, posture and smaller muscle mass stabilizing the coxofemoral joint are the main reasons for the increased intolerance (8, 20, 30).

Power et al 2010 (19) compared the relationship between OFA hip joint score with PennHIP DI. The study showed that a wide range of dogs had passive joint laxity measured by DI but were considered phenotypically normal by the OFAS hip joint score. In average 52 % of the dogs scored excellent hip joints, 82 % of dogs with good hip joints, and 94 % of dogs with fair hip joints had a DI of >0,3. This suggests that the OFA scoring with HE radiographs underestimates the dogs susceptible for developing OA. Interestingly in this study 77 % of the Golden Retrievers and 88 % of the Labrador Retrievers where certified for breeding. Of these dogs 100% of the Golden Retrievers and 89 % of the Labrador Retrievers were judged as OA susceptible by the DI method. In August 2009 the mean value for DI of Golden Retrievers were 0,55, and only 1,2 % of these had a DI of <0,3. The study concludes that continuing breeding of OFA normal dogs will unlikely improve the breeds overall laxity profile and OA susceptibility (19).

A Cohort study of 48 Labrador Retrievers followed for life showed that a young age and restricted food intake had profound beneficial effects on the ventrodorsal HE radiograph scored by the OFAs. The DI was not influenced by environmental factors such as weight and diet restrictions and remained constant through life and therefore the heritability is likely of a higher trait (29).
The PennHIP DI phenotype has a

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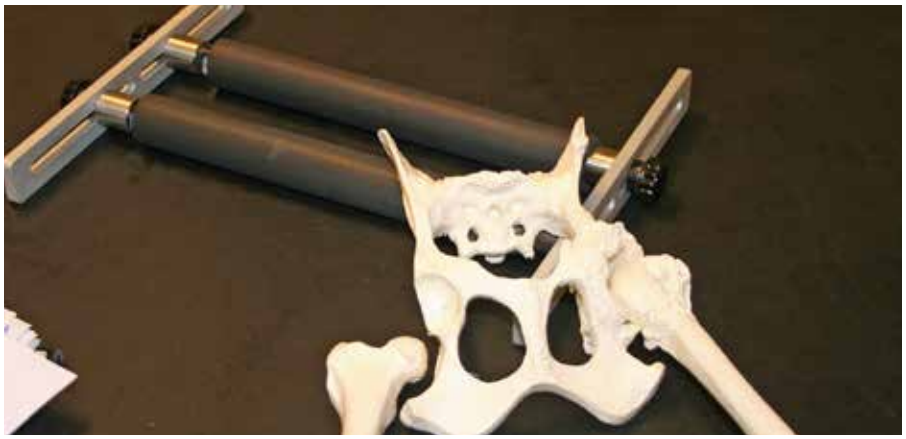

potentially greater heritability than the HE radiographic phenotype, and could therefore improve breeding for healthier hip joints, although a genetic evaluation of the PennHIP database has yet to be conducted (33, 39). The DI is breed-specific, therefore the breed susceptibility could be incorporated when making breeding decisions (30). As many authors suggest (6, 18, 26, 29, 30, 32, 39) the DI is an easy method that can give practical recommendations to breeders to genetically select a better hip phenotype by using a DI below median for that breed. The use of dogs with a lower DI would impose a greater selection pressure and result in a more rapid genetic improvement. The PennHIP database does not have an open register as would be desirable to help breeders select and combine breeding dogs. Although, if accepted as a screening method or as supplement to current screening methods in one of the larger hip screening organization the database would probably automatically be available publically.

In Sweden only a few clinics perform PennHIP radiographs. In 2013 one breed club (unknown) requested the SKC to introduce a requirement that all dogs in the breed should undergo PennHip and that the result should be registered. The SKC breeding panel's report from 2013 established that the PennHIP method is not as good as the FCI screening method in larger dog populations and rejected the application (35). A personal comment about this was: *The SKC requires from a breeding perspective as much information about individuals, and populations within the breed to achieve a selection pressure, which is not possible with the PennHIP today. The method takes longer time to perform and requires only PennHIP certified veterinarians that are trained to officially perform the PennHIP procedure, and the education to become PennHIP certified is located in the USA which is a limiting factor. The PennHIP report confides the veterinarian and dog owner, but is not open for public and therefore the usefulness is limited from a breeding perspective* (Sofia Malm, SKC, Stockholm, personal message, 2016).

Today the PennHIP certification course is available online and for free if three passing radiographs has been approved within 45 days. The clinics that want to use the PennHIP method have to invest in a PennHIP device to be able to perform the procedure (2).

Conclusion

CHD is a polygenic disease with a complex inheritance and a multifactorial disorder which complicates the selection for healthy breeding. Selection using the HE radiographic has had only a modest success in reducing the amount of CHD and underestimates susceptible individuals developing osteoarthritis and is influenced by environmental factors such as weight. The PennHIP is a multifaceted radiographic screening method considered to be best method evaluating hip laxity. The use of dogs with a lower DI would impose a greater selection pressure and result in a more rapid genetic improvement for healthier hip joints. Therefore the PennHIP method should be used as a breeding supplementation, although the screening results should be open in public. Dogs selected for breeding should also have radiographic hip evaluations regularly through life as DJD expression may not be radiographically evident until later in life.

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