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The Norberg angle is not an accurate predictor of canine hip conformation based on the distraction index and the dorsolateral subluxation score

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ABSTRACT

Canine hip dysplasia (CHD) is a common complex trait characterized by abnormal hip joint development. Hip joint laxity, an early characteristic of CHD, results in degeneration of the joint due to mechanical trauma, which is a clinical problem mostly in medium to large breed dogs. Clinical signs include pain, decreased activity and lameness. A retrospective, multi-center, cross sectional study of 437 dogs was performed to determine if a Norberg angle (NA) $\geq$105° accurately predicts a non-dysplastic hip based on a distraction index (DI) cut-off of $\leq$0.3 or a dorsolateral subluxation (DLS) score cut-off of $\geq$55%. The predictive capacity of the NA against a DI $\leq$0.3 or a DLS score $\geq$55% was assessed using area under the receiver operator characteristic (ROC) curve analysis. The ROC curve of NA for the prediction of a DI $\leq$0.3 was 0.59 (95% CI = 0.50–0.69) and for the prediction of DLS score $\geq$55% was 0.69 (95% CI = 0.63–0.75). Optimizing the specificity of the NA to $\geq$80% for prediction of a DI $\leq$0.3 and a DLS score $\geq$55% gave a cut-point for the NA of $\geq$112° and 108.7°, respectively. In conclusion, at the cut-point of 105°, the NA is not an accurate measurement to score normal or abnormal hips, based on the DI or DLS score. Application of screening methods for CHD based on hip laxity, such as the DI or the DLS score, would help to remove additional dysplastic dogs from the breeding pool or the NA criterion should be higher when selecting unaffected dogs for breeding.

1. Introduction

Canine hip dysplasia (CHD) is an inherited, developmental trait with both genetic and environmental factors such as sex, age, growth rate, and body condition affecting its expression (Zhang et al., 2009; Powers et al., 2010; Wilson et al., 2011). First described in 1935 (Schnelle, 1935), it has been the subject of intensive research and methods for reproductive control because it is one of the most common, and clinically-important, orthopedic traits of the dog. Canine hip dysplasia continues to be prevalent in large and giant dog breeds reaching 48.1% in St. Bernard, 47.6% in Boykin Spaniel (Corley, 1992), 59.7% in Cane Corso (Genevois et al., 2008), 65.8% in Serra da Estrela Dogs (Ginja et al., 2009b), 57% in German Shepherd (Grosu et al., 2013), and 29.6% in Molossoid breeds (Lavrijsen et al., 2014).

The diagnosis of CHD is worldwide based on characteristic radiographic signs observed on the standard ventrodorsal (VD) hip-extended projection in dogs older than 1 or 2 years of age (Ginja et al., 2010). However, a predisposition to CHD can be identified at earlier ages using hip joint laxity determination (Smith et al., 1990; Farese et al., 1998). The Norberg Angle (NA) is determined on the VD view, being a measure of the relationship between the femoral head and the acetabulum (Morgan and Stephens, 1985). The NA is used in some national and at least in two important international CHD scoring systems: the *Fédération Cynologique Internationale* (FCI) and the British Veterinary Association/Kennel Club (BVA/KC) (Gibbs, 1997; Ginja et al., 2010). The FCI scores CHD in five categories using as reference the most dysplastic hip and the NA $\geq$105° is the main

Abbreviations: BVA/KC, British Veterinary Association/Kennel Club; CHD, canine hip dysplasia; CI, confidence interval; DI, distraction index; DJD, degenerative joint disease; DLS, dorsolateral subluxation; FCI, Fédération Cynologique Internationale; ICC, intraclass correlation coefficient; NA, Norberg angle; NPV, negative predictive value; OFA, Orthopedic Foundation for Animals; PPV, positive predictive value; ROC, receiver operator characteristic; VD, ventrodorsal.

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criteria to score normal or borderline hips (Douglas, 1970; Morgan and Stephens, 1985). Other FCI categories are reserved for dysplastic hips (mild, moderate and severe CHD), which have a NA <105° and evidence of radiographic signs of degenerative joint disease (DJD) (Flückiger, 2007; Ginja et al., 2010; Verhoeven et al., 2012). The BVA/KC grading system classifies each hip individually with a score ranging from 0 to 53 and the sum over both hips from 0 to 106. The BVA/KC higher scores indicate worse hip status and the NA of each hip is scored from 0 (NA ≥ 105°) to 6 (NA < 80°) (Gibbs, 1997; Dennis, 2012). Another international CHD scoring system is applied through the Orthopedic Foundation for Animals (OFA) in the USA and Canada. This organization scores CHD into seven categories (three normal, one borderline and three dysplastic), does not use the NA, and scoring is focused on hip conformation associated with joint congruity, subluxation and signs of DJD (Corley, 1992).

Hip laxity is considered the main risk factor to predict the development of DJD in dysplastic hips (Smith et al., 2001; Todhunter et al., 2003b). The presence of DJD signs on a radiograph is considered the clinical gold standard for diagnosis of CHD. Radiographic methods used to estimate hip joint laxity are the PennHIP and the dorsolateral subluxation (DLS) test (Smith et al., 1990; Farese et al., 1998). The PennHIP method is used in dogs older than 4 months of age and is used to calculate the distraction index (DI) (Smith et al., 1990). The DI measures the relative displacement of the geometric center of the femoral head from the center of the acetabulum when lateral stress is applied to the proximal femur by a PennHIP distractor (Smith et al., 1990). The DLS test reveals hip joint subluxation by positioning dogs in a weight-bearing position at 4 to 8 months of age (Farese et al., 1998). The DI and DLS are negatively correlated, dogs with tight hips (DI ≤0.3 or DLS score ≥55%) are significantly less likely to develop CHD than dogs with loose hips (DI >0.7 or DLS score <45%) (Smith et al., 1990; Farese et al., 1998; Todhunter et al., 2003a).

The main purpose of this study was to determine the ability of the NA ≥105° to predict a non-dysplastic hip based on a DI ≤0.3 cut-off or a DLS ≥55% cut-off.

2. Materials and methods

2.1. Animals

This was a retrospective multi-center cross sectional study conducted on 437 dogs from both clinical and research settings that underwent screening for CHD using VD radiographic projections, distraction method projections or DLS projections, between 1998 and 2015. The dogs were radiographed at Cornell University Hospital for Animals (USA), at the Veterinary Teaching Hospital of University of Trás-os-Montes and Alto Douro (Portugal) or at the Baker Institute for Animal Health at Cornell University College of Veterinary Medicine (USA). Recorded data included animal sex, age at the time of the radiographs, breed, bodyweight, body score condition and geographic location of evaluation.

The inclusion criteria were availability of pelvic radiographs that allowed assessment of either the NA and DI, the NA and DLS score, or all three projections on the same dog, at concurrent time points. Due to the observational nature of the study, the client consent was waived.

2.2. Sedation

For the radiographic study, different sedation protocols were used: at Cornell University Hospital for Animals, a combination of medetomidine (0.02 mg/kg IV) and butorphanol (0.1 mg/kg IV) was used prior to 2007 and then was replaced with dexmedetomidine (0.005 mg/kg IV) and butorphanol (0.1 mg/kg IV); at the Veterinary Teaching Hospital of University of Trás-os-Montes and Alto Douro medetomidine (0.02 mg/kg IV), butorphanol (0.1 mg/kg IV) and atropine sulphate (0.020 mg/kg IV) was used; while acepromazine (0.02 mg/kg IV) and glycopyrrolate (0.010 mg/kg SQ) and then anesthesia was induced with propofol (6 mg/kg IV), and maintained with inhalant halothane at the Baker Institute for Animal Health.

2.3. Radiographic projections and measurement

For the VD projection, dogs were placed in dorsal recumbency on the X-ray table, with the rear limbs extended parallel to each other and to the table top, and the stifles internally rotated (Corley, 1992; Ginja et al., 2010). The NA measurements were performed by RJT or MMG, on digital images visualized in imaging software[1,2] or on hard copy radiographs. The NA was measured in degrees between a line drawn connecting the center of both femoral heads and a line connecting the center of the femoral head and the craniolateral aspect of the ipsilateral acetabular rim (Henricson et al., 1966; Comhaire and Schoonjans, 2011).

For the distraction projection, dogs were placed in dorsal recumbency on the X-ray table, with hips at a neutral position and the flexed stifles pointing vertical to the table top. The examiner pushed both rear limbs medially at the level of the tibia against the PennHIP distractor which was placed between them, thus forcing the femoral heads away from the acetabulum (Smith et al., 1990). This view was performed by RJT or MMG. The DI was calculated at the PennHIP Analysis Center.[3]

For the DLS projection, dogs were radiographed in sternal recumbency in a kneeling position with the stifles in an opening in a foam pad or in an acrylic positioning device (Ogden et al., 2012), with the femora approximately perpendicular to the table, the stifles flexed and the hock joints extended (Farese et al., 1998; Lust et al., 2001). The DLS measurements were performed by RJT on digital images using imaging software[1] or on hard copy radiographs. A best fitting circle was placed over each femoral head to calculate their diameter. For the determination of the DLS score, a line was drawn connecting both craniolateral edges of the acetabular rims. Then, two perpendicular lines were dropped from this line at the most medial edge of the femoral head and at the craniolateral edge of the acetabulum, respectively. The displacement distance between these perpendicular lines was measured. The DLS score was determined by dividing this distance by the ipsilateral femoral head diameter (Farese et al., 1998).

2.4. Statistical analysis

One hip from each dog was randomly selected for the statistical analysis. Descriptive statistics were computed for all variables. Normality was assessed using graphical methods and the Shapiro-Wilk test. Continuous data are presented as mean ± standard deviation where normal or median and interquartile range for non-normal distribution and categorical data as number (%) unless otherwise indicated. All comparisons were two-tailed and $p < 0.05$ was considered to be statistically significant. T-tests were conducted where data was normal and Mann-Whitney tests where data was not normal. We performed univariable logistic regression analyses against binary outcomes as the dependent factors consisting of DI ≤0.3 and DLS score ≥55% for non-dysplastic and DI >0.3 and DLS <55% for dysplastic hips. The NA was considered as the independent variable. The Hosmer Lemeshow goodness-of-fit test was performed

[1] CARESTREAM Vue PACS. Carestream Health, Inc. Rochester, NY.
[2] OSIRIS Version 3.1. University Hospitals of Geneva. Geneva, Switzerland.
[3] PennHip. Synbiotics Inc. Malvern, PA.