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EVALUATION OF RADIOGRAPHIC COXOFEMORAL MEASUREMENTS IN BOERBOEL DOGS

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ABSTRACT

This study compares the coxofemoral parameters used for the detection of hip dysplasia in humans with Norberg angles in Boerboel dogs. Twenty adult Boerboel dogs of both sexes (mean weight: 54.0 ± 7.54 kg) were used. They were premedicated with Xylazine (0.5 mg.kg^{-1}) and induced with a propofol (4 mg.kg^{-1}) injection. Extended antero-posterior radiographs of the hip were obtained with a digital X-ray machine. Linear Femoral Overlap (LFO), Norberg Angle (NA), Sourcil Sector Angle (SSA), Center Edge Angle (CEA) and Acetabular Index Angle (AIA) were determined. The inter- and intra-observer variability were calculated from inter- and intra- class correlation coefficient using the analysis of variance (ANOVA). Fischer's exact test was used to define the statistically significant difference in measurements between sexes and hip dysplasia status. A significant difference was set at $P < 0.05$. The intra-observer agreement was high for NA and CEA, moderate for AIA, but low for SSA and LFO, while inter-observer agreement was high for NA and CEA, moderate for LFO and AIA, but very low for SSA. There was no significant ($P < 0.05$) difference in the measured parameters between male and female Boerboels, however, NA and CEA were significantly ($P < 0.05$) lower in Boerboels with hip dysplasia than those with normal hips. The CEA does not have advantage over NA for radiographic screening of dogs with hip dysplasia.

Key words: Boerboel; coxofemoral; dogs; hip dysplasia; radiographic

INTRODUCTION

Canine hip dysplasia is a hereditary degenerative joint disease of the hip joint resulting in sub-luxation and remodeling of the head of the femur and/or acetabulum [1]. The reduced hip stability mostly result from excessive laxity of the joint capsule and ligament, and poor congruence of the femoral head within the cranial/dorsal aspect of the acetabulum. It occurs in all breeds, with higher prevalence in middle and large breeds of dogs, and breeds with rapid growth [15]. It is one of the most common orthopaedic disorders in dogs, representing 30 percent of orthopaedic cases [14]. Offspring control and elimination of parents producing poor offspring are effective in reducing the prevalence of canine hip dysplasia [18]. Breed value estimations based on non-biased progeny testing can also reduce the incidence markedly. Although a lot of efforts have been made to control the diseases in dogs, the prevalence is still high depending on the quality of the selection mode [17].

The qualitative method for the screening of dogs for hip dysplasia is based on the description of the radiological characteristics [4]. These include the methods of the Orthopaedic Foundation for Animal (OFA), the Federation Cynologique International (FCI) [21], and the British Veterinary Association/Kennel club (BVA/KC) [7]. These methods assess the degree of laxity of the hip joint by inward rotation of the femoral head and extension of the hip joints to obtain a cranio-lateral distraction. Other criteria are the degree of remodeling and the radiological severity of the osteoarthritis.

Various measurements have been used in the radiographic diagnosis of canine hip dysplasia, and in the evaluation of the hip joint before and after surgical procedures [8, 19]. The common measurement criteria include the Norberg angle, [12], surface femoral overlap [19], PennHip distraction index [6, 16] and dorsal acetabular rim angle [20]. The Norberg angle was first described in 1961 by Olsson and others [3]. It measured the position of the femoral head in relation to the acetabulum. A larger Norberg angle reflects a deeper acetabulum and more tightly fixed hip joints, but a lower Norberg angle reflects varying degrees of a subluxation [1]. The normal Norberg angle is described to be 105 degrees or more for a normal hip. Conventional methods for measuring the Norberg angle have been found to be dependent on scrutineer's training and expertise, limiting its possible usefulness [2]. In addition, the cranial acetabular rim which is an important radiographic landmark in the measurement of Norberg angle is normally displaced centrally after triple pelvic osteotomy (TPO) surgery [8], making radiographic projection after TPO not identical to the presurgical situation.

In humans, the Center Edge Angle of Wiberg, Sharp Acetabular Index of weight bearing surface, and recently the Sourcil Sector Angle are used in quantitative measurements of the acetabular coverage area and early identification of hip dysplasia [22]. These measurements were found to have lower inter-observer variability [22]. However, they are yet to be evaluated in dogs for reliability and repeatability.

The Boerboel is a big, strong and intelligent working dog. It is well balanced with good muscle development and buoyant in movement. Boerboel are believed to have originated from South Africa and was thought to be a crossbreed between Bullmastiff and the local South African dog breeds like the Bullenbijter. Boerboels are generally known for their good health, but suffer from hip and/or elbow dysplasia [5]. Although, the exact prevalence of hip dysplasia in Boerboel is unknown, the percentage of Boerboel with hip dysplasia reported at the Orthopaedic Foundation for Animal (OFA) database is estimated to be 47.3 percent [13]. This probably explains why hip radiograph is a prerequisite for Boerboel appraisal.

In spite of currents efforts at radiographic screening for hip dysplasia, the prevalence of the disease is still high. The problem may be multifactorial ranging from poor parent selection by breeders, low quality examiners missing dysplastic dogs, breeding with dysplastic dogs; extremely low offspring control rate and not submitting radiographs of obviously dysplastic dogs for evaluation. Thus, there is a need for a more effective and reliable means for radiographic detection of dysplastic dogs before commencement of breeding.

This study evaluated radiographic measurements used for the detection of hip dysplasia in humans for their reliability and effectiveness in dogs and compared them with the traditional Norberg angle measurements in dogs.

MATERIALS AND METHODS

Twenty client-owned adult Boerboel dogs of both sexes with a mean weight of 54.0 ± 7.54 kg and aged between 14 and 30 months were used. They were presented for routine hip and elbow radiographs for certification under the Kennel Union of South Africa (KUSA). They were adjudged to be clinically healthy based on the results of a physical examination and complete blood counts. All of the dogs used were identified with a microchip and registered with the Boerboel Dog Breeders Association of Nigeria (BDBAN) or the Boerboel Alliance (BA). Before the commencement of the study, informed owner's consent was obtained. The study was approved by the Ethical and Animal Care and

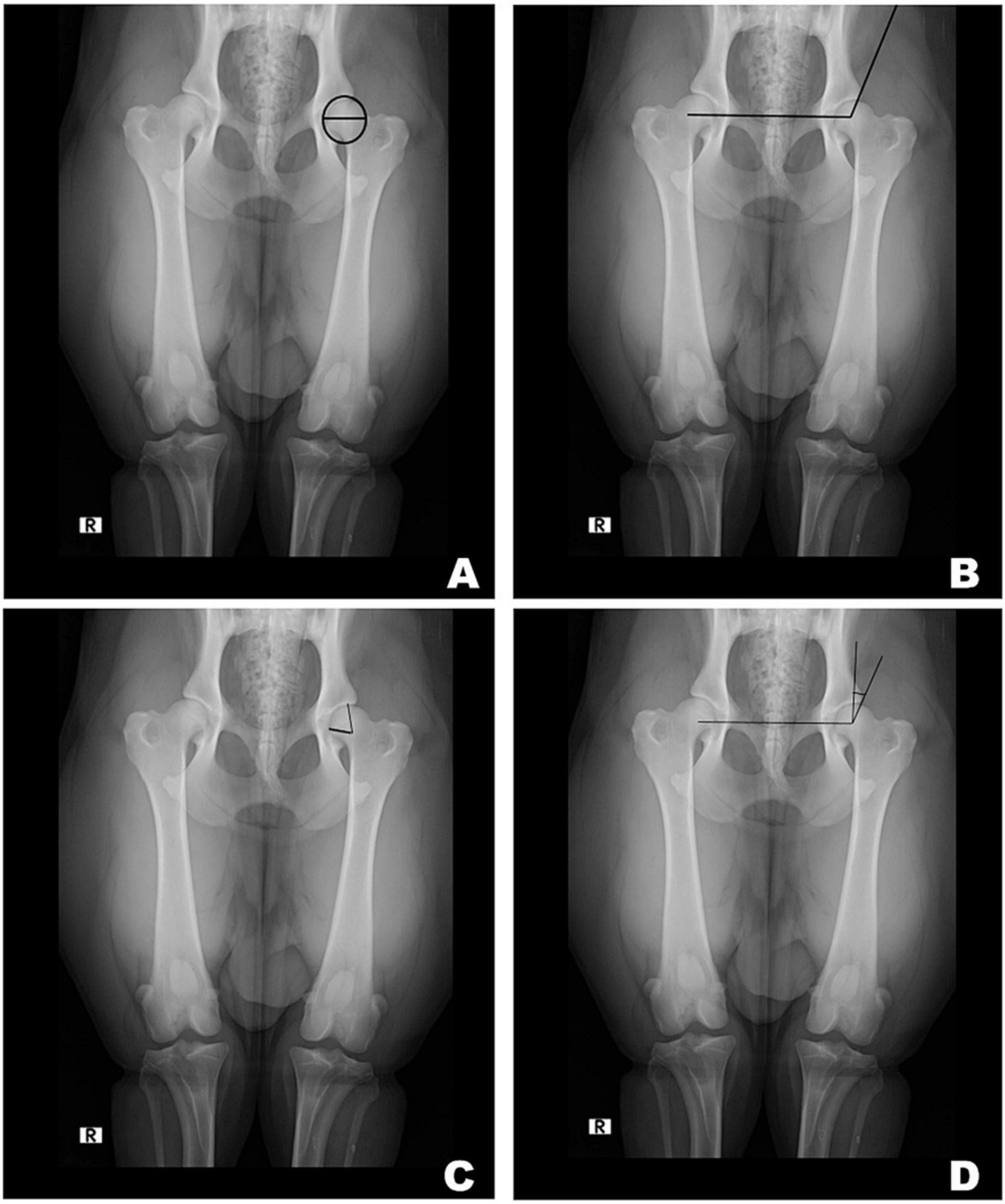

Fig. 1. Measurements of linear femoral overlap (A), Norberg angle (B), Sourcil sector angle (C) and Centre edge angle (D) in Boerboel dogs

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The dogs were premedicated with intramuscular injections of 0.5 mg/kg of 2 xylazine hydrochloride (Xylazine 20 Inj®, Kepro, Holland) and 0.04 mg.kg^{-1} atropine sulphate (Atocan®, Sishui Xierkang Pharma, China). Thereafter, anaesthesia was induced with 4 mg.kg^{-1} of 1 % propofol injection (Diprivan, ICI-Zeneca Pharmaceuticals) intravenously. Extended antero-posterior radiograph of the hip joints with the dog in dorsal recumbency was obtained in all of the dogs using a digital X-ray machine with a Potter-Bucky grid. Exposure factors ranged from 10—16 mAs and 74—80 KvP, depending on the size of the dog.

Following radiographic examinations, the radiographs were printed out and measurements were taken. Measurements were taken twice for both the right and left coxofemoral joint by two independent observers. The following measurements (Figure 1) were determined from each radiograph:

- **Linear Femoral Overlap:** A diameter line was drawn through the center of the femoral head and perpendicular to the longitudinal body axis. The linear femoral overlap was the percentage of the line that was covered by the acetabulum [8].
- **Norberg Angle:** The angle between a line starting at the center of the femoral head and drawn to the intersection between the craniolateral and dorsal acetabular margin of the acetabulum, and a line connecting the left and right femoral head [1].
- **Sourcil Sector Angle:** the angle formed between two lines from the rotational center of the femur and the medial and lateral extent of the acetabular dorsal subchondral bone plate [22].
- **Center Edge Angle of Wiberg:** It is defined by two straight lines originating from the center of the femoral head, the first tangential to the acetabular rim and the second parallel to the mid-sagittal line [10].
- **Acetabular Index Angle:** It is the angle formed between the tangential line to the acetabulum to the point of the lateral contact with the femoral head and a line normal to the mid-sagittal plane [22].

Data were presented as mean and standard deviation. Inter and Intra class correlation coefficient were calculated to estimate inter- and intra-observer variability using the analysis of variance (ANOVA). Fischer's exact test was used to define statistically significant differences in the measurements between male and female dogs, and normal and dysplastic dogs. The level of significance was set at $P < 0.05$.

Table 1. Intra-class correlation coefficient of left coxofemoral measurement in Boerboel dogs

Coxofemoral measurements	Mean ± SD	Correlation coefficient	Significance
Linear Femoral Overlap [%]	57.87 ± 4.82	0.455	0.138
Norberg Angle [°]	106.25 ± 6.94	0.980	0.008
Sourcil Sector Angle [°]	67.58 ± 16.53	0.438	0.066
Centre Edge Angle [°]	17.31 ± 6.63	0.829	0.003
Acetabular Index Angle [°]	19.15 ± 3.47	0.678	0.032

Table 2. Inter-class correlation coefficient of right coxofemoral measurement in Boerboel dogs

Coxofemoral measurements	Mean ± SD	Correlation coefficient	Significance
Linear Femoral Overlap [%]	51.49 ± 9.11	0.650	0.042
Norberg Angle [°]	111.54 ± 18.00	0.856	0.000
Sourcil Sector Angle [°]	84.83 ± 9.06	0.126	0.575
Centre Edge Angle [°]	23.75 ± 3.88	0.842	0.002
Acetabular Index Angle [°]	21.17 ± 5.44	0.742	0.052

RESULTS

Intra-observer agreement for the five measured coxofemoral parameters is shown in Table one. The level of agreement was high for Norberg angle (NA) and Centre Edge Angle (CEA), moderate for Acetabular Index Angle (AIA), but low for Sourcil Sector Angle (SSA) and Linear Femoral Overlap (LFO). Similarly, inter-observer agreement was high for the Norberg angle (NA) and Centre Edge Angle (CEA), moderate for Linear Femoral Overlap (LFO) and Acetabular Index Angle (AIA), but very low for Sourcil Sector Angle (SSA) (Table 2).

The mean and standard deviation of the five coxofemoral parameters on the right hip of the Boerboel dogs is shown in Table 3. There was no significant difference in all of the measured coxofemoral parameters between male and female Boerboel dogs. Table 4 showed the mean and standard deviation of the five coxofemoral parameters on the left hip of the Boerboel dogs. There was no significant difference in all the coxofemoral parameters between male and female Boerboel dogs.

The mean and standard deviation of the five coxofemoral parameters on the right hip of the Boerboel dogs are shown in Table 5. The Norberg Angle (NA) and the Centre Edge Angle (CEA) were significantly ($P < 0.05$) higher in non-dysplastic Boerboels dogs than Boerboels with hip dysplasia. The other parameters were not significantly ($P < 0.05$) different between the normal and dysplastic Boerboel dogs. Table 6 showed the mean and standard deviation of the five coxofemoral parameters on the left hip of the Boerboel dogs. The Norberg Angle (NA) and the Centre Edge Angle (CEA) were significantly ($P < 0.05$) higher in non-dysplastic Boerboels dogs than Boerboels with hip dysplasia. Other measured parameters were not significantly $P < 0.05$) different between normal and dysplastic Boerboel dogs.

DISCUSSION

The results of this study revealed that the level of intra- and inter-observer agreements were very high for NA and CEA, moderate for AIA, but low for SSA and LFO. In addition, there was no significant ($P < 0.05$) difference in all of the coxofemoral parameters between the male and female Boerboels for both coxofemoral joints, but NA and CEA were significantly ($P < 0.05$) lower in Boerboels with hip dysplasia than those with normal hip.

Table 3. Right limb coxofemoral measurements in male and female Boerboel dogs

Coxofemoral measurements	Male Boerboels	Female Boerboels
Linear Femoral Overlap [%]	59.72 ± 5.08	54.94 ± 15.97
Norberg Angle [°]	105.20 ± 6.61	105.43 ± 3.29
Sourcil Sector Angle [°]	77.00 ± 14.20	66. 24 ± 11.14
Centre Edge Angle [°]	17.90 ± 3.00	19.21 ± 6.58
Acetabular Index Angle [°]	19.30 ± 3.83	17.76 ± 4.76

Table 4. Left limb Coxofemoral measurements in male and female Boerboel dogs

Coxofemoral measurements	Male Boerboels	Female Boerboels
Linear Femoral Overlap [%]	63.54 ± 8.34	61.60 ± 10.08
Norberg Angle[°]	104.40 ± 5.94	104.93 ± 7.91
Sourcil Sector Angle [°]	69.00 ± 8.49	69.00 ± 10.81
Centre Edge Angle [°]	16.30 ± 2.33	18.50 ± 5.01
Acetabular Index Angle [°]	19.00 ± 5.00	15.64 ± 6.01

Table 5. Right limb coxofemoral measurements in dysplastic and non-dysplastic Boerboel dogs

Coxofemoral measurements	Non-dysplastic Boerboels	Dysplastic Boerboels
Linear Femoral Overlap [%]	57.04 ± 15.03	56.78 ± 6.98
Norberg Angle [°]	107.71 ± 4.18	98.00 ± 3.16*
Sourcil Sector Angle [°]	72.07 ±14.07	69.40 ± 12.80
Centre Edge Angle [°]	20.86 ± 5.15	15.60 ± 3.92*
Acetabular Index Angle [°]	18.64 ± 5.33	18.1 ± 2.79

*P < 0.05

Table 6. Left limb coxofemoral measurements in dysplastic and non-dysplastic Boerboel dogs

Coxofemoral measurements	Non-dysplastic Boerboels	Dysplastic Boerboels
Linear Femoral Overlap [%]	62.41 ± 7.64	62.40 ± 20.56
Norberg Angle [°]	107.36 ± 4.14	96.00 ± 1.58*
Sourcil Sector Angle [°]	70.64 ± 10.18	66.70 ± 8.9
Centre Edge Angle [°]	19.57 ± 3.63	14.80 ± 3.21*
Acetabular Index Angle [°]	16.43 ± 3.64	17.90 ± 4.77

*P < 0.05

The Norberg angle (NA) (the angle between a line starting at the center of the femoral head and drawn to the intersection between the craniolateral and dorsal acetabular margin of the acetabulum and a line connecting the left and right femoral heads) is measured on the conventional hip extended radiograph and quantifies the position of the femoral head in relation to the acetabulum [1]. The larger NA reflects a deeper acetabulum and more tightly fitting hip joint, whereas a lower NA reflects a variable degrees of subluxation. The NA is the gold standard criteria used for phenotypic screening of dogs with hip dysplasia by the Orthopaedic Foundation for Animals (OFA) and the Fédération Cynologique Internationale (FCI). In this study, NA was found to have high intra-observer and inter-observer agreement when compared with other coxo-femoral measurements. This further confirms the high reproducibility of NA for the screening of dogs with hip dysplasia.

The Linear Femoral Overlap (LFO) is also a measure of the total acetabular coverage of the femoral head and indicates how deep seated is the femoral head inside the acetabulum [8]. It is presumed that LFO is much easier to measure than the Norberg angle and required no special software. However, the degree of correlation between LFO and NA has been reported to be low. In this study, the intra-observer agreement was low for LFO, while the inter-observer agreement was moderate. The moderate inter-observer agreement implies that the reproducibility of the measurement between different observers is not high and suggests that the parameter may be not be as accurate as a screening criteria for canine hip dysplasia. Our findings of moderate inter-observer agreement were contrary to that earlier reported [8].

The Centre Edge Angle is formed by a vertical line connecting the femoral head centre with the lateral edge of the acetabulum [23]. It is an important landmark in the development of osteoarthritis in humans and has been used to classify humans as either dysplastic or normal. This is the first attempt at evaluating the usefulness of the centre edge angle in dogs. In this study, both the inter-observer and intra-observer agreement was high. In addition, the centre edge angle was significantly lower in dysplastic Boerboel dogs than the non-dysplastic dogs. The values obtained for dogs in this study are in agreement with the earlier studies in humans [9]. This suggests the possible usefulness of the centre edge angle in radiographic assessments of dogs for hip dysplasia. However, the CEA does not appear to have any advantage over the traditional Norberg angle

The Sourcil Sector Angle was presented at the International Society for Hip Arthrotomy in Cambridge, 2015 [22]. It is a measurement of the upper lateral Sourcil of the acetabulum and is highly indicative of acetabular dysplasia in humans. Both the inter-observer and intra-observer agreement for the Sourcil Sector Angle was very low in this study suggesting probably the difficulty in determining the land marks for its measurement in dogs and may imply that the angle is not reliable in the radiographic assessment of hip dysplasia in dogs.

The Acetabular Index Angle is a radiographic measurement used in evaluating the potential developmental dysplasia in humans. The angle is formed by a horizontal line connecting both triradiate cartilages and a second line extending along the acetabular roofs [11]. In dogs, the Acetabular Slope Angle was proposed in 1990 [10]. Previous studies in dogs showed that the Acetabular Index Angle showed a higher reliability than the Acetabular Slope Angle [10]. In our study, both the intra- and inter-observer agreement was moderate for the acetabular index angle. However, there was no significant difference in the Acetabular Index Angle between normal and dysplastic Boerboel dogs, suggesting that the parameters cannot be used to differentiate between normal and dysplastic dogs.

In conclusion, the results of our study demonstrated that apart from the Norberg Angle, the Centre Edge Angle can also be used for screening of dogs with hip dysplasia. Although, the Acetabular Index Angle had moderate inter- and intra-observer variability, the measurements failed to discriminate between normal and dysplastic dogs. However, the Centre Edge Angle does not have any advantage over the Norberg angle in the radiographic screening of dogs for hip dysplasia and suggested that the Norberg angle is still the most reliable measurements for the detection of hip dysplasia in dogs.

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