B-4941
[1-7]

RESEARCH ARTICLE Indian Journal of Animal Research

Morphometry of Hip Joint in German Shepherd Dogs with Hip Dysplasia vis-a-vis Normal Hip

Jagan Mohan Reddy Kataru, Veena Podarala, Suresh Kumar Rayadurgam Venkata, Shanthi Lakshmi Mukku, Veda Samhitha Jampala

10.18805/IJAR.B-4941

ABSTRACT

Background: Data on measurements of the proximal femur, acetabulum with special reference to CHD in GSD is relatively limited. The present study recorded the complete canine femoral geometry of healthy as well as dysplastic hip joint in young dogs of GSD breed.

Methods: All the dogs were subjected to radiographic evaluation to measure hip joint morphometric parameters using the CARESTREAM vita flex CR system with added IMAGE SUITE software version 4.0.

Result: In dogs below 6 months of age and with CHD, measurements like AW, HD were higher in CHD where as ND, FIA values were lower. AA, EAA values were higher and AHI was lower in CHD. Indices like DI and SI were higher whereas PC and NA were lower in CHD. In healthy hip, HNI and PC values were higher in male dogs where as FNALa, ND values were higher in female dogs. In CHD, FSC, HD, TW, FSD, FIA were higher in female dogs where as HAL value was higher in male dogs. In dogs between 6 to 12 months age and with CHD, FNALa, FNALb values were higher, where as AW, ND, FSD, FIA values were lower in CHD. AA, EAA values were higher, where as AHI, PC were lower in CHD. Indices like DI and SI were higher, whereas PC and NA were lower in CHD. In dogs with healthy hip, FNALa, FNALb, TW, AHI values were higher in male dogs where as AW, AHI values were higher in female dogs. In CHD, AW, TW were higher in female dogs where as HAL, FSC, ND, FSD values were higher in male dogs.

Key words: CHD, Hip Morphometric measurements.

INTRODUCTION

Canine Hip Dysplasia (CHD) is one of the most commonly diagnosed orthopaedic diseases in dogs. Imaging of the canine pelvis coupled with physical examination findings are the principle methods used to screen for and diagnose CHD. Determination of hip joint metrics will aid in early detection of CHD and facilitate a better outcome in hip pathologies.

MATERIALS AND METHODS

The present study was conducted on GSD dogs presented to Department of Surgery and Radiology, College of Veterinary Science, Sri Venkateswara Veterinary University, Tirupati, over a period of one year (2020-2021). GSD breed dogs (n=32) with healthy hip joints (n=8) or with a history and clinical symptoms suggestive of hip dysplasia (n=24) were selected and divided equally into two groups based on the age.

Group I: GSD breed dogs aged below six months.

Group II: GSD breed dogs aged between six to twelve months.

All the dogs were subjected to radiographic evaluation for measuring hip joint morphometric parameters using The CARESTREAM vita flex CR system with added IMAGE SUITE software version 4.0. The research work was carried out after approval from Institutional Animal Ethics Committee vide No 281/GO/ReBi/S/2000/CPCSEA/CVSc/TPTY/007/Surgery/2020 dated 30.01.2020.

Hip morphometric measurements included Hip Axis Length (HAL) - Length from junction of femoral neck axis and lateral aspect of the greater trochanter to the pelvis, Femoral Axis Length (FNALa) – length along the femoral neck axis from junction of femoral neck axis and lateral aspect of the greater trochanter up to caput femoris , FNALb- length along the femoral neck axis from junction of femoral neck axis and lateral aspect of the greater trochanter centre of the caput femoris, Acetabular Width (AW), Femoral Shaft Cortex width (FSC) - cortical thickness just below the trochanter minor and perpendicular to the femoral diaphysis, Femoral Head Diameter (HD) - distance between the intersection point of femoral head centre and femoral neck axis and perpendicular to femoral neck axis; Femoral Neck Diameter (ND) - shortest distance within the femoral neck, perpendicular to the femoral neck axis, Trochanteric Width

Department of Veterinary Surgery and Radiology, College of Veterinary Science, Sri Venkateswara Veterinary University, Tirupati-517 502 andhra Pradesh, India.

Corresponding Author: Veena Podarala, Department of Veterinary Surgery and Radiology, College of Veterinary Science, Sri Venkateswara Veterinary University, Tirupati-517 502 andhra Pradesh, India. Email: vienoa8893@gmail.com

How to cite this article: Kataru, J.M.R., Podarala, V., Venkata, S.K.R., Mukku, S.L. and Jampala, V.S. (2022). Morphometry of Hip Joint in German Shepherd Dogs with Hip Dysplasia Vis a Vis Normal Hip. Indian Journal of Animal Research. DOI: 10.18805/IJAR.B-4941.

Submitted: 23-05-2022 **Accepted:** 30-09-2022 **Online:** 31-10-2022

(TW)- distance between just above the trochanter minor and the most lateral point of trochanter major, Femoral Shaft Diameter (FSD) - distance between just below the trochanter minor and perpendicular to the femoral diaphysis, Femoral Inclination Angle (FIA) - the angle formed at the proximal femoral diaphysis, halfway between trochanter minor and the most lateral point of trochanter major along the line of femoral diaphysis and head- neck index of Heyman and Herndon (Fig 1-4), Acetabular angle (AA), external acetabular angle (EAA) and acetabulum head index (AHI)

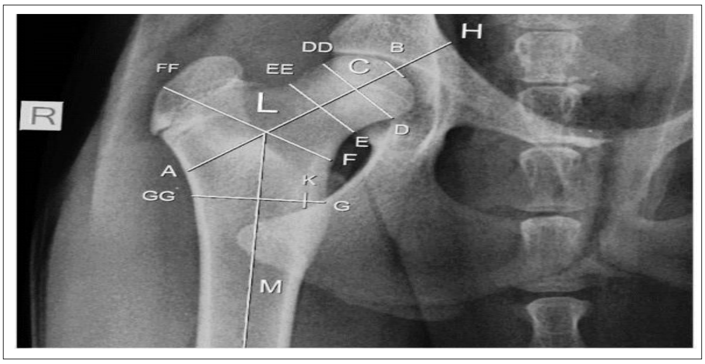

Fig 1: Skiagram showing Proximal femoral measurements in dogs with healthy hip joint.

Proximal femrol measurements. **HAL:** The distance betwen A and H, along the femrol neck axis, defined as the length from junction of femrol neck axis and lateral aspect of the greater trochanter to the pelvis); **FNALa:** The distance between A and B (length along the femrol neck axis from junction of femrol neck axis and lateral aspect of the greater troucher to the caput femories) and **FNALb:** The distance between A and C (lenth along the femrol neck axis from junction of femrol neck axis and lateral aspect of the greater troucher to the caput femories); **AW:** The distance between B and H: **FSC:** Cortical thickness at the level G-GG line (just below the trochanter minor and prependicular to the femrol diaphysis); **HD:** The distance between D and DD (at the intersection point of the femrol head centre and femrol neck axis and prependicular to the femrol neck axis; **ND:** The distance between E and EE (the shortest distance betwen within the femrol neck perpendicular to the femrol neck axis); **TW:** The distance between F and (between just above the trochanter minor and the most lateral point of the trochanter major); **FSD:** The distance between G GG (just below the trochanter miner and prependicular to the femrol diaphysis); **FIA:** The angle of CLM points; K: cortical thickness of femrol diaphysis along the G-GG line; L-M: axis of the femrol diaphysis.

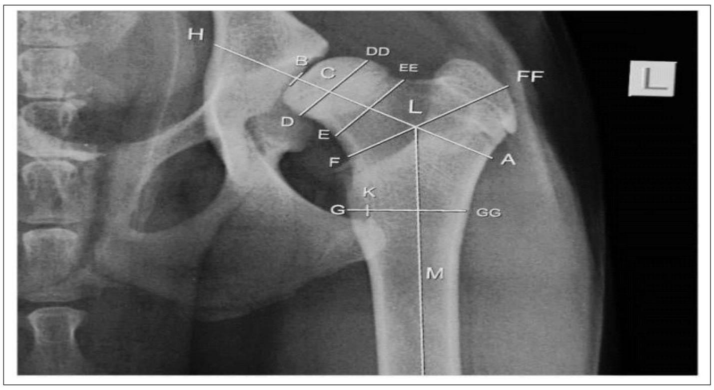

Fig 2: Skiagram showing Proximal femoral measurements in CHD.

Proximal femrol measurements. **HAL:** The distance betwen A and H, along the femrol neck axis, defined as the length from junction of femrol neck axis and lateral aspect of the greater trochanter to the pelvis); **FNALa:** The distance between A and B (length along the femrol neck axis from junction of femrol neck axis and lateral aspect of the greater troucher to the caput femories) and **FNALb:** The distance between A and C (lenth along the femrol neck axis from junction of femrol neck axis and lateral aspect of the greater troucher to the caput femories); **AW:** The distance between B and H: **FSC:** Cortical thickness at the level G-GG line (just below the trochanter minor and prependicular to the femrol diaphysis); **HD:** The distance between D and DD (at the intersection point of the femrol head centre and femrol neck axis and prependicular to the femrol neck axis; **ND:** The distance between E and EE (the shortest distance betwen within the femrol neck perpendicular to the femrol neck axis); **TW:** The distance between F and (between just above the trochanter minor and the most lateral point of the trochanter major); **FSD:** The distance between G GG (just below the trochanter miner and prependicular to the femrol diaphysis); **FIA:** The angle of CLM points; K: cortical thickness of femrol diaphysis along the G-GG line; L-M: axis of the femrol diaphysis.

(Fig 5-10), Percentage coverage (PC), Norberg Angle (NA), Distraction Index (DI) and Sub luxation index (SI) (Fig 11-18). The data collected were statistically analyzed using SPSS- software version 17.0, TWO WAY ANOVA and Tukey's Post Hoc test.

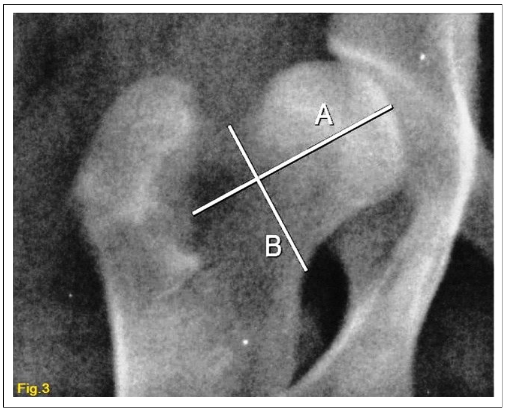

Fig 3: Skiagram showing HNI measurement in dogs with healthy hip joint.
Head-neck index of Heyman and Herndon (A/B × 100: A: total length of femoral head and neck. B: femoral neck width at the narrowest point).

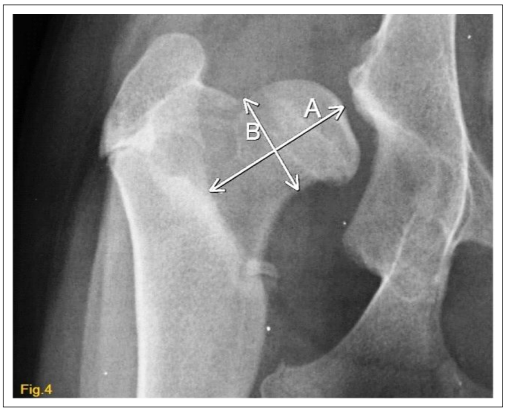

Fig 4: Skiagram showing HNI measurement in CHD.
Head-neck index of Heyman and Herndon (A/B × 100: A: total length of femoral head and neck. B: femoral neck width at the narrowest point).

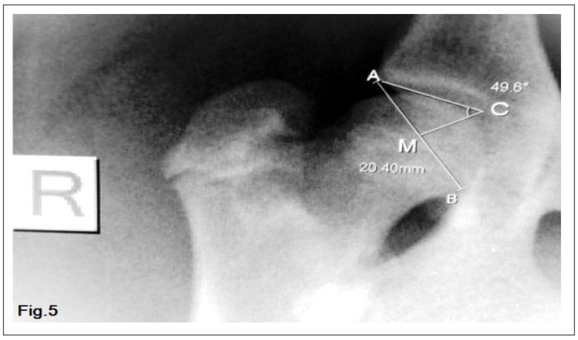

Fig 5: Skiagram showing Acetabular Angle measurement in dogs with healthy hip joint.

RESULTS AND DISCUSSION

Data on hip morphology on the breed would provide an opportunity for more sensitive treatment planning and better outcome in CHD. Complete hip joint metrics in GSD breed dogs are discussed in the present study.

GSD breed dogs below 6 months of age (Group I)

Mean ± S.E values of hip joint metrics and *p*-values showing only significant difference ($p<0.05$) are presented in Table 1.

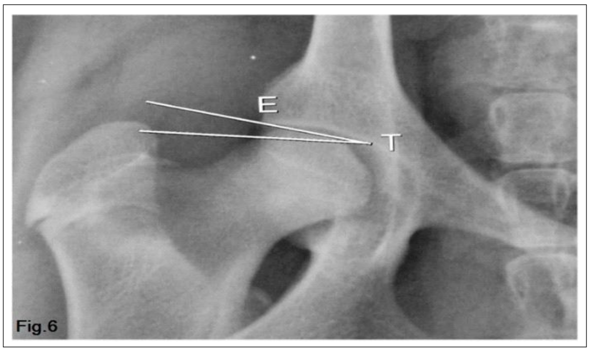

Fig 6: Skiagram showing EAA measurement in dogs with healthy hip joint.

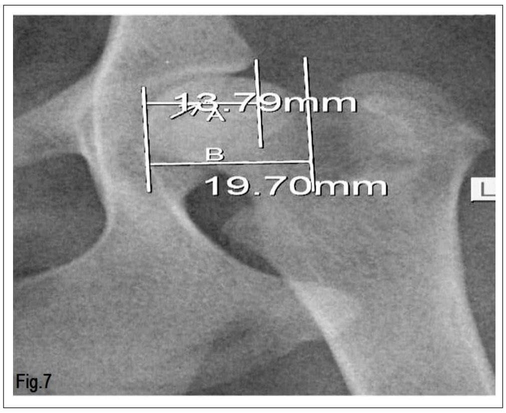

Fig 7: Skiagram showing AHI measurement in dogs with healthy hip joint.

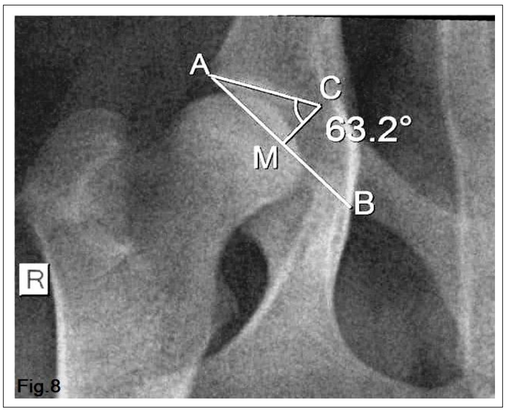

Fig 8: Skiagram showing Acetabular Angle measurement in CHD.

HAL is the distance along the femoral neck axis from the base of the greater trochanter to the inner pelvic brim. Higher HAL value was associated with increased femoral neck width and HAL is related to femoral strength.

HAL values differed non significantly between healthy hip joint and CHD. Within the group of dogs with healthy hip joint, non significant difference in HAL values were observed between male and female dogs and right and left hip joints. HAL was significantly higher in male Sivas Kangal dogs with healthy hip joints (Sarierler *et al.* 2017). On the contrary, in the present study, in CHD, HAL values were higher in male dogs. HAL values were similar in unilateral or bilateral CHD.

Non significant difference in FNALa and FNALb values were observed between healthy hip joint and CHD and between right and left limbs irrespective of CHD. FNALa

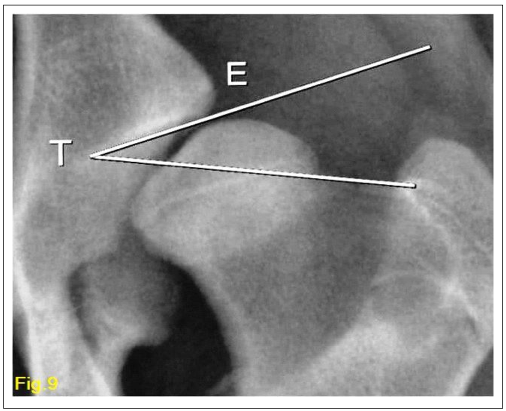

Fig 9: Skiagram showing EAA measurement in CHD.

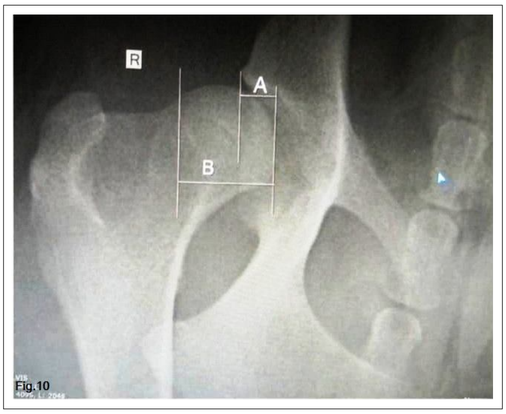

Fig 10: Skiagram showing AHI measurement in CHD.

Fig 11: Skiagram showing percentage coverage of femoral head in healthy hip joints in dogs.

Fig 12: Skiagram showing percentage coverage of femoral head in CHD.

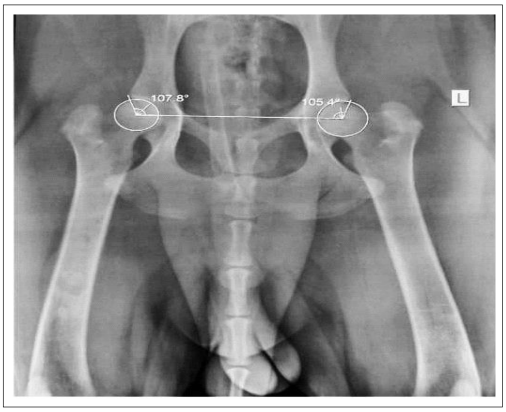

Fig 13: Skiagram showing Norberg Angle measurement in healthy hip joint in dogs.

Fig 14: Skiagram showing Norberg Angle measurement in CHD.

values were significantly higher in female dogs with healthy hip. FNALb values were significantly higher in unilateral CHD.

AW values were significantly higher in dogs with CHD. AW values were similar in male and female dogs, in right and left limbs of all dogs. AW values were significantly higher in bilateral CHD and on higher side in female dogs with unilateral CHD and in male having bilateral CHD.

FSC values were similar in dogs with healthy hip joint or with CHD. Within the group of dogs with healthy hip joints there was non significant difference among male and females, in right and left limbs. FSC was higher in female dogs in CHD and higher in bilateral CHD. FSC was thicker in male dogs with a healthy hip joint in Sivas Kangal breed (Sarierler *et al.* 2017).

HD was significantly different between healthy hip and CHD. Dogs with CHD had higher HD values. Within the group of dogs with healthy hip joint, there was non significant difference between male and female dogs, in right and left limbs. In CHD, female dogs had significantly higher HD values. HD values were similar in unilateral and bilateral CHD.

ND values were significantly higher in dogs with healthy hip joint. Within the group of dogs with healthy hip joints female dogs had significantly higher ND values. TW values were similar in all dogs irrespective of CHD. TW values were significantly higher in female dogs with CHD. TW values were similar in unilateral or bilateral CHD.

FSD values were similar in all dogs irrespective of CHD. Within the group of dogs with CHD, FSD values were higher in female dogs. FSD values were similar in unilateral and bilateral CHD. FSD values were higher in female dogs in unilateral CHD.

FIA is biomechanically important in the transfer of forces from the femur to the acetabulum and increased FIA was reported in CHD (Madsen and Svalastoga, 1994). An association between hip status and inclination angle was recorded (Hauptman *et al.* 1985 and Sarierler, 2004). There was significant difference in FIA values between dogs with healthy hip joint and CHD. FIA values were similar in male and female dogs, in right and left limbs when the hip joint was healthy, where as in CHD, FIA values were significantly higher in male dogs.

There was no variation HNI values between dogs with healthy hip joint and CHD. Among dogs with healthy hip joint, HNI values were significantly higher in male dogs. HNI values were higher in unilateral CHD.

The acetabular angle (AA/ACM) derived by Idelberger and Frank is a measure of the acetabular depth. AA values were significantly higher in CHD (Tonnis, 1987) in the present

Fig 15: Skiagram showing distraction view.

Fig 17: Skiagram showing stress view.

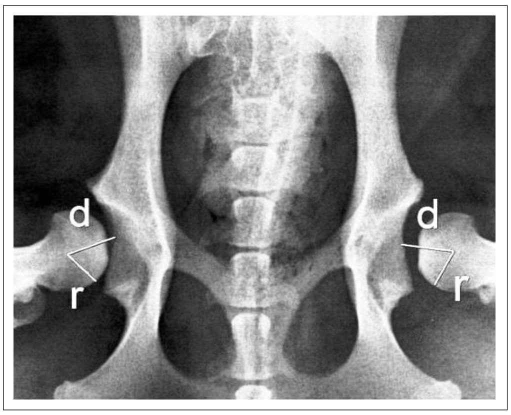

Fig 16: Skiagram showing measurement of distraction index (DI).

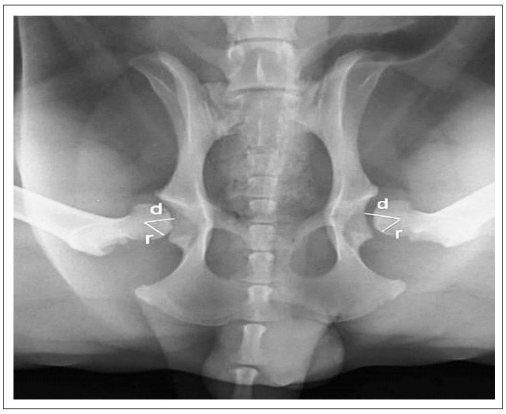

Fig 18: Skiagram showing measurement of Sub-luxation Index(SI).

Table 1: Showing Hip measurements in GSD breed dog groups I and II.

Interactions	Proximal femoral measurements										Acetabular measurements					Other measurements		
	HAL	FNALa	FNALb	AW	FSC	HD	ND	TW	FSD	FIA°	HNI	AA	EAA	AHI	PC %	NA°	DI	SI
Healthy vs. CHD		2	2	1,2		1	1,2		2	1,2		1,2	1,2	1,2	1,2	1,2	1,2	1,2
Between Gender - Healthy hip		1,2,	2	2			1	2			1		2	2	1			
Limb laterality - Healthy hip																		
Between Gender – CHD	1,2			2	1,2	1	2	1,2	1,2	1								
Limb laterality – CHD																		
Male - Healthy vs. CHD	1,2			1	2	2	1	2		1,2		1,2	1,2	1,2	1,2	1,2	1,2	1,2
Female - Healthy vs. CHD		1,2	2	1,2		1	1,2	1,2	2	1,2		1,2	1,2	1	1,2	1,2	1,2	1,2
Right Limb - Healthy vs CHD			2	1		1	1,2		2	1,2		1,2	1,2	1,2	1,2	1,2	1,2	1,2
Left Limb - Healthy vs. CHD			2	1			1,2		2	1,2		1,2	1,2	1,2	1,2	1,2	1,2	1,2
Unilateral vs. Bilateral CHD			1	1	1						1,2		1	1,2	1,2	1,2	2	1,2
Male vs Female Unilateral CHD	1,2			1,2	2		2	1,2,	1,2	1,2			1,2	1				
Male vs. Female Bilateral HD	1,2			1,2	1		2	1,2,								1		

1- Significant difference ($p \leq 0.05$) observed in Group-I GSD breed dogs only; 2 - Significant difference ($p \leq 0.05$)observed in Group-II GSD breed dogs only.
1, 2- Significant difference ($p \leq 0.05$) observed in both the groups of GSD breed dogs.

study. AA values were similar between male and female dogs, right or left limbs irrespective of CHD.

EAA values were significantly higher in CHD. Higher EAA values were observed in cases of acetabular dysplasia (Delaunay *et al.* 1997). EAA values were similar in male and female dogs, right and left limbs irrespective of CHD. EAA values were significantly higher in unilateral CHD and male dogs had higher EAA values in unilateral CHD.

Normal AHI values ranged between 70% and 90%, with an average of 90% (Tonnis, 1987). In the present study, AHI values were significantly higher in dogs with healthy hip joint. AHI values were similar in male and female dogs, right and left limbs whether the hip joint was healthy or dysplastic. AHI values were significantly higher in unilateral CHD and male dogs had higher AHI values in unilateral CHD.

Subluxation is reported to be minimal when 50 per cent of the diameter of the femoral head is within the acetabulum (Farese *et al.* 1998 and Tomlinson and Johnson, 2000). Norberg angle (Tomlinson and Johnson, 2000) different distraction indices (Heyman *et al.* 1993) and the percentage coverage of the femoral head (Tomlinson and Johnson 2000) have been used to assess the degree of lateral displacement of the femoral head from the acetabulum. In the present study, PC values were significantly higher in dogs with healthy hip joint (Lopes *et al.* 2018) and male dogs had higher PC values within the healthy dogs. PC values were higher in unilateral CHD.

NA is a quantitative method of assessing the hip joint for dysplasia and is commonly considered a measure of laxity (Adams *et al.* 2000). A normal hip was reportedly considered to have an NA greater than 105° and it is more likely that the dog will develop osteoarthritis as the subluxation progresses (Lust *et al.* 2001). Dogs with healthy hip joint had significantly higher NA values. NA values did not differ significantly between male and female dogs, right and left limb in all the dogs. Significantly higher NA values were observed in dogs with unilateral CHD and female dogs had higher NA values in bilateral CHD.

Measurement of the DI involves measuring relative displacement of the femoral head from the acetabulum on a stress radiographic view of the pelvis. A DI value of 0.3 was established as a susceptibility threshold value for DJD (Kapatkin *et al.* 2002). In the present study significantly higher DI and SI values were observed in dogs with CHD. SI values were significantly higher in bilateral CHD. DI and SI values did not differ significantly between male and female dogs, right and left limbs within the group of dogs with healthy or dysplastic hip joint.

GSD breed dogs between 6 to 12 months of age (Group II)

Mean ± S.E values of hip joint metrics and *p*-values showing only significant difference (*$p<0.05$*) are presented in Table 1. HAL values were non significantly different between healthy hip joint and CHD. HAL values were similar in male and female dogs and in right and left limbs in healthy hip joint. HAL was significantly higher in male Sivas Kangal dogs with healthy hip joints. HAL values were significantly different between male and female dogs in CHD where in male dogs had higher HAL values. HAL values were similar in unilateral or bilateral C HD.

FNALa and FNALb values were significantly higher in CHD. In dogs with healthy hip joint, male dogs had significantly higher FNALa and FNALb values. Similar observation was recorded in Sivas Kangal dog breed (Sarierler *et al.* 2017). FNALa and FNALb values were higher in female dogs in CHD.

AW values were non significantly different between dogs with healthy hip joint and dogs with CHD. Female dogs had higher AW values irrespective of whether the hip joint was healthy or dysplastic or whether the CHD was unilateral or bilateral. On the contrary, higher AW values were recorded in male Sivas Kangal breed dogs with healthy hip joint.

There was non significant difference in FSC values between dogs with healthy hip joint and dogs with CHD. Within the group of healthy hip joints FSC values were similar in male and females and in right and left limbs. On the contrary, FSC was thicker in male dogs of Sivas Kangal breed (Sarierler *et al.* 2017). In the present study, FSC values were significantly higher in male dogs in CHD. The FSC values were similar in unilateral and bilateral CHD.

HD values were similar in dogs with healthy hip joints and in CHD. Non significant difference was observed in between male and female dogs, between right limb and left limb either in healthy hip joint or in CHD, however, male dogs with CHD had higher HD values than male dogs with healthy hip joint.

ND values were significantly higher in dogs with healthy hip joint with no difference in ND values between male and female dogs, right and left limbs. Within the dogs with CHD, ND values were higher in male dogs. The ND values were similar in unilateral and bilateral CHD.

TW values were non significantly different between dogs with healthy hip joint and dogs with CHD where as male dogs with healthy hip joint had significantly higher TW values than female dogs of the same group. On the contrary, in CHD, TW values were higher in female dogs. Male dogs with a healthy hip joint had significantly higher ND values than the male dogs with CHD whereas female dogs with a healthy hip joint had significantly lower ND values compared to female dogs with CHD. TW values were similar in unilateral and bilateral CHD.

FSD values were significantly higher in dogs with healthy hip joint. FSD values were similar in male and female dogs, in right limb and left limb when the hip was healthy where as in CHD, FSD values were significantly higher in male dogs. FSD values were similar in unilateral and bilateral CHD.

FIA values were significantly higher in dogs with healthy hip joint. No such difference was recorded in FIA values by some researchers (Hauptman *et al.* 1985) whereas higher FIA values were recorded in CHD (Madsen and Svalastoga, 1994) by other researchers. In the present study, FIA values were similar in male and female dogs, in right limb and left limbs irrespective of CHD. Age and sex did not affect the FIA values (Hauptman *et al.* 1985). FIA values were similar in unilateral and bilateral CHD and male dogs had higher FIA values when the CHD was unilateral.

HNI values were similar in all dogs irrespective of CHD, sex and limb laterality. HNI values were significantly different higher in unilateral CHD. AA values were significantly higher in dogs with CHD (Tonnis, 1987) Within the group of dogs with healthy hip joint or with CHD, AA values between male and female dogs, right or left limbs did not differ significantly.

EAA values were significantly higher in dogs with CHD. Higher EAA values were observed in acetabular dysplasia (Delaunay *et al.* 1997). Within the group of dogs with healthy hip joint, EAA values were significantly higher in male dogs.

EAA values were similar in unilateral and bilateral CHD. Male dogs had significantly higher EAA values in unilateral CHD.

AHI values were significantly higher in dogs with healthy hip joint and male dogs had significantly higher AHI values within the group. AHI values were significantly higher in unilateral CHD. PC values were significantly higher in dogs with healthy hip joint. PC values were similar in male and female dogs, right and left limbs irrespective of CHD. PC values were significantly higher in dogs with unilateral CHD.

Dogs with healthy hip joint had significantly higher NA values. NA values did not differ significantly between male and female dogs, right and left limbs irrespective of CHD. NA values were significantly higher in dogs with unilateral CHD.

DI and SI values were significantly higher in CHD. Within the group of dogs with healthy hip joint and with CHD, both DI and SI values did not differ significantly between male and female dogs, right and left limbs. Significantly higher DI and SI values were observed in bilateral CHD.

CONCLUSION

To conclude, in dogs below 6 months of age and with CHD, measurements like AW, HD were higher in CHD whereas ND, FIA values were lower. AA, EAA values were higher and AHI was lower in CHD. Indices like DI and SI were higher whereas PC and NA were lower in CHD. In dogs between 6 to 12 months age and with CHD, FNALa, FNALb values were higher, whereas AW, ND, FSD, FIA values were lower in CHD. AA, EAA values were higher, whereas AHI, PC were lower in CHD. Indices like DI and SI were higher, whereas PC and NA were lower in CHD.

Conflict of interest: None.

REFERENCES

Adams, W.M., Dueland, R.T., Daniels, R., Fialkowski, J.P., Nordheim, E.V. (2000). Comparison of two palpation, four radiographic and three ultrasound methods for early detection of mild to moderate canine hip dysplasia. Veterinary Radiology Ultrasound. 41(6): 484-490.

Delaunay, S., Dussault, R.G., Kaplan, P.A., Alford, B.A. (1997). Radiographic measurements of dysplastic adult hips. Skeletal Radiology. 26(2): 75-81.

Farese, J.P., Todhunter, R.J., Lust, G., Williams, A.J., Dykes, N.L. (1998). Dorsolateral subluxation of hip joints in dogs measured in a weight bearing position with radiography and computed tomography. Veterinary Surgery. 27(5): 393-405.

Hauptman, J., Cardinet 3rd, G.H., Morgan, J.P., Guffy, M.M., Wallace, L.J. (1985). Angles of inclination and anteversion in hip dysplasia in the dog. American Journal of Veterinary Research. 46 (10): 2033-2036.

Heyman, S.J., Smith, G.K., Cofone, M.A. (1993). Biomechanical study of the effect of coxofemoral positioning on passive hip joint laxity in dogs. American Journal of Veterinary Research. 54(2): 210-215.

Kapatkin, A., Fordyce, H.H., Mayhew, P., Smith, G.K. (2002). Canine Hip Dysplasia: Disease and its diagnosis. Compendium on Continuing Education for the Practicing Veterinarian. 24(7): 526-538.

Lopes, L.S., Selmi, A.L., Lins, B.T., Macedo, A.S. (2018). Clinical and radiographic evaluation of double pelvic osteotomy to treat canine hip dysplasia. Ciencia Rural. 48(4): 1-4.

Lust, G., Todhunter, R.J., Erb, H.N., Dykes, N.L., Williams, A.J., Burton-Wurster, N.I., Farese, J.P. (2001). Comparison of three radiographic methods for diagnosis of hip dysplasia in eight-month-old dogs. Journal of the American Veterinary Medical Association. 219(9): 1242-1246.

Madsen, J.S. and Svalastoga, E. (1994). Inclination and anteversion of collum femoris in hip dysplasia and coxarthritis. Acta Veterinaria Scandinavica. 35(2): 115-119.

Sarierler, M. (2004). Comparison of femoral inclination angle measurements in dysplastic and non-dysplastic dogs of different breeds. Acta Veterinaria Hungarica. 52(2): 245-252.

Sarierler, M., Tatli, Z.B., Akin, I., Yaygingul, R., Derincegoz, O.O. (2017). Radiographic examination of hip joint geometry in healthy Sivas Kangal dogs. Turkish Journal of Veterinary and Animal Sciences. 41(1): 85-92.

Tonnis, D. (1987). Etiology of congenital dislocation of the hip. Congenital Dysplasia and Dislocation of the Hip in Children and Adults. 58-59.

Tomlinson, J.L. and Johnson, J.C. (2000). Quantification of measurement of femoral head coverage and Norberg angle within and among four breeds of dogs. American Journal of Veterinary Research. 61(12): 1492-1500.