Research Article

Radiographic examination of hip joint geometry in healthy Sivas Kangal dogs

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Abstract: The aim of this study was to determine the normal ranges of proximal femoral and acetabular parameters in 26 adult healthy Sivas Kangal dogs (SKDs). Significant differences were observed between the sexes in hip axis length (HAL) of 8.03 ± 0.82 cm and 7.47 ± 0.40 cm, femoral neck axis length-a (FNALa) of 6.40 ± 0.55 cm and 6.09 ± 0.27 cm, FNALb of 5.09 ± 0.47 cm and 4.78 ± 0.31 cm, acetabular width (AW) of 1.62 ± 0.35 cm and 1.37 ± 0.24 cm, femoral shaft diameter (FSD) of 3.11 ± 0.31 cm and 2.88 ± 0.21 cm, and acetabular angle (ACM) of 44.04 ± 3.32° and 42.16 ± 2.94° in males and females, respectively. No significant differences were observed between the sexes in femoral shaft cortex width, femoral head diameter, femoral neck diameter, head-neck index, trochanteric width, femoral inclination angle, external acetabular angle, and acetabulum-head index. Males had longer HAL ($P < 0.01$), FNALa and FNALb ($P < 0.05$), and AW ($P < 0.01$) and thicker FSD ($P < 0.01$) and wider ACM ($P < 0.05$) than bitches. In this study, normal ranges in healthy SKDs of proximal femoral and acetabular parameters related to certain hip joint pathologies in humans were presented.

Key words: Sivas Kangal dog, acetabulum, proximal femur, hip, geometry, radiography

1. Introduction

Hip joint disorders, including fractures and dislocations of the femoral head and neck, epiphysiolysis, Legg–Calve–Perthes disease, and canine hip dysplasia (CHD), constitute a significant part of the orthopedic problems in dogs. These problems may be exacerbated depending on different genetic and environmental effects or trauma. For instance, large and giant breeds are more likely to have the genetic predisposition for CHD than slim and small breeds (1–4). The Sivas Kangal, which is a valuable, large breed of dog in Turkey, is a breed predisposed for CHD. The incidence of CHD in Sivas Kangal dogs (SKDs) was reported as 19.11%–62% (2,5,6). Although there were no published reports on this topic, we have encountered some problems such as epiphysiolysis of the femoral head and fractures and dislocations of the hip joint in SKDs in our clinics.

Based on the standardized values obtained through various studies (7,8) on radiographic measurements of the proximal femur and acetabulum in humans, some pathological conditions of hip joints could be evaluated more objectively, and they also have an important role in the evaluation of bone resistance and strength (9). Alterations in the proximal femoral and/or acetabular geometry may cause changes in load distribution on the hip joint and intraarticular structure resulting in joint laxity, CHD, and secondary osteoarthritis (OA) formation. For example,

the femoral inclination angle (FIA) is important for load transferring from the femur to the acetabulum, and increased FIA has also been reported in CHD (10). The hip axis length (HAL) had greater sensitivity and specificity than bone mineral density for predicting fracture risk (11). Heyman and Herndon measured the head and neck dimensions of the femurs in humans to derive the head-neck index. The head-neck quotient measures the overall deformity of the proximal femur, secondary to avascular necrosis with metaphyseal involvement. In humans, the normal value is approximately 100. A smaller quotient indicates greater deformity relative to the opposite side (8). The acetabular angle (ACM), derived by Idelberger and Frank, is the measure of the acetabular depth that is practically invariant with pelvic rotation, pelvic tilt, and age (8). The ACM angle increases in dysplastic hips (8). The external acetabular angle (EAA) is derived from the horizontal toit extern (HTE) angle, which is used to evaluate the acetabular roof's orientation at the coronal plane and lateral coverage level of the head in humans and is 10° or lower for a healthy human. A higher HTE is observed mostly in cases of acetabular dysplasia (12). The acetabulum-head index (AHI) measures the percentage of the covered surfaces of the femoral head by the acetabulum (13). Normal head coverage, according to Heyman and Herndon (1950), is between 70% and 90%, with an average of 90% (8).

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Although many parameters related to the proximal femur and acetabulum have been studied in humans, the studies carried out on the measurements of the proximal femur and acetabulum in dogs mostly have been limited to the measurement of Norberg, inclination, and anteversion angles (13–16). OA (13) and breed (6) also may affect these parameters. The structure of the proximal femur and the biomechanics of the hip joint may interact. Some of these parameters may vary in humans depending on ethnicity (17). These differences are seen more markedly among dog breeds, which have very different body structures from one to another (18). Determination of some parameters belonging to the proximal femur and acetabulum for healthy SKDs will generate data for hip morphology on the breed and provide an opportunity for more sensitive treatment planning, especially for total hip replacement, and better outcome of different hip pathologies.

The aim of this study was to determine the normal ranges in healthy SKDs of some proximal femoral and acetabular parameters related to certain hip joint pathologies in humans.

2. Materials and methods

Some morphometric parameters belonging to the proximal femur and acetabulum based on studies in humans (7–9) were measured in 26 adult (older than 12 months) SKDs with healthy hip joints according to clinical and radiological examinations. The dogs were obtained by performing health screening for CHD at Sivas Kangal breeding farms. To select the dogs with healthy hip joints, 80 dogs were evaluated with inclusion criteria of having a Norberg angle over 105° and no pathological changing of the femoral head-neck and acetabulum. Radiographs were taken in standard hip-extended position, under xylazine HCl (Rompun, Bayer, at 1 mg/kg dose rate, intravenously) and ketamine HCl (Ketalar, Eczacıbaşı, at 2 mg/kg dose rate, intravenously) anesthesia following premedication with subcutaneous administration of atropine sulfate at 0.02 mg/kg dose rate (Atropin, Vetaş).

Radiographs were scanned using a personal computer and scanner at 300 dpi resolution and JPEG images were transferred to MediCAD Veterinary (Hectec GmbH) computer software. After calibration of JPEG images, measurements were taken. Most of the proximal femoral measurements were performed along the femoral neck axis. For drawing the femoral neck and proximal femoral axes, the modified symmetric axis-based (symax) method of Rumph and Hathcock (15) was used. One circle was placed exactly within the head of the femur. Three other circles were placed at the neck, proximal, and middle parts of the femur so that they touched the silhouette boundary. Straight lines were drawn between these circle centers and thus the neck and proximal femoral axes were drawn (15).

After that, the parameters, shown in Tables 1 and 2 and Figures 1–5 (8,9,12,19), were measured from the images using the MediCAD Veterinary computer software.

Proximal femoral measurements included hip axis length (HAL), femoral neck axis length (FNALa and FNALb), acetabular width (AW), femoral shaft cortex width (FSC), femoral head diameter (HD), femoral neck diameter (ND), trochanteric width (TW), femoral shaft diameter (FSD), femoral inclination angle (FIA) (Figure 1), and head-neck index of Heyman and Herndon (HNI) (Figure 2).

Acetabular measurements included acetabular angle (ACM, derived from the acetabular angle of Idelberger and Frank) (Figure 3), external acetabular angle (EAA, derived from the HTE angle) (Figure 4), and acetabulum-head index (AHI) (Figure 5).

The results were analyzed using SPSS 10.0. Compliance with the normality assumption of data was checked with the Shapiro–Wilk test. The homogeneity of variances was controlled by Levene's test. Since the HAL-total variable did not meet the assumptions of normality, logarithmic transformation was applied. The effects of sex and left-right sides on the parameters were evaluated by two-way analysis of variance, and $P < 0.05$ was considered significant. Results were given as mean ± standard deviation (SD). To assess the repeatability of the method, the coefficients of variation (CVs) were calculated for each measurement as SD divided by the mean multiplied by 100, following the measuring of all parameters ten times from a randomly selected image by the first author (MS).

3. Results

Measurements of the proximal femur and acetabulum are presented in Tables 1 and 2, respectively. For all measurements, two-way analysis of variance was applied to investigate whether there was a statistical difference between left and right sides, and between sexes. Consistent with the literature (18), no significant differences between sides were observed. However, there were significant differences in some parameters between sexes. Therefore, the dogs were grouped according to sex without distinction between the right and left side; a total of 52 hip joints, consisting of 30 hip joints from 15 male dogs and 22 hip joints from 11 female dogs, were evaluated and analyzed statistically. The HAL ($P < 0.01$), FNALa ($P < 0.05$), FNALb ($P < 0.05$), and AW ($P < 0.01$) were longer and FSC was thicker and acetabular angle was greater in males than in females. Other parameters did not show significant differences by sex.

Related to the repeatability of the study, nonsignificant differences were observed for each parameter according to CV (ranging from 0.45% to 2.94%). The femoral inclination angle represents the parameter that is the most repeatable

Table 1. Measurements of the proximal femur.

Parameters	N	HAL (cm)	FNALa (cm)	FNALb (cm)	AW (cm)	FSC (cm)
Male-right	15	8.07 ± 0.90	6.39 ± 0.58	5.10 ± 0.49	1.67 ± 0.36	0.36 ± 0.10
Male-left	15	7.99 ± 0.76	6.41 ± 0.54	5.07 ± 0.47	1.57 ± 0.35	0.37 ± 0.09
Total (male)	30	8.03 ± 0.82[a]	6.40 ± 0.55[a]	5.09 ± 0.47[a]	1.62 ± 0.35[a]	0.36 ± 0.10
Female-right	11	7.48 ± 0.36	6.13 ± 0.23	4.82 ± 0.29	1.36 ± 0.24	0.37 ± 0.05
Female-left	11	7.45 ± 0.46	6.06 ± 0.31	4.75 ± 0.35	1.39 ± 0.25	0.37 ± 0.05
Total (female)	22	7.47 ± 0.40[b]	6.09 ± 0.27[b]	4.78 ± 0.31[b]	1.37 ± 0.24[b]	0.37 ± 0.05
Right (R)	26	7.82 ± 0.77	6.28 ± 0.48	4.99 ± 0.43	1.54 ± 0.35	0.37 ± 0.09
Left (L)	26	7.76 ± 0.69	6.26 ± 0.48	4.93 ± 0.45	1.50 ± 0.32	0.37 ± 0.08
Total (R+L)	52	7.79 ± 0.72	6.27 ± 0.48	4.96 ± 0.44	1.52 ± 0.33	0.37 ± 0.08
CV(%)	10	0.57	0.85	0.62	1.87	2.80
		P-value				
Sex		0.008	0.021	0.013	0.007	0.739
Right-left		0.783	0.855	0.631	0.714	0.858
Sex × R-L interaction		0.937	0.745	0.877	0.445	0.739

[a, b]: Differences between values marked with different letters in the same column are significant. ($P < 0.05$).

Parameters	N	HD (cm)	ND (cm)	HNI	TW (cm)	FSD (cm)	FIA°
Male-right	15	2.71 ± 0.29	2.33 ± 0.29	191 ± 24	4.43 ± 0.67	3.12 ± 0.33	132.63 ± 4.15
Male-left	15	2.67 ± 0.23	2.37 ± 0.28	193 ± 21	4.51 ± 0.44	3.10 ± 0.30	133.18 ± 5.03
Total (male)	30	2.69 ± 0.26	2.35 ± 0.28	192 ± 22	4.47 ± 0.44	3.11 ± 0.31[a]	132.91 ± 4.55
Female-right	11	2.66 ± 0.18	2.21 ± 0.19	207 ± 20	4.23 ± 0.18	2.88 ± 0.21	132.27 ± 3.46
Female-left	11	2.58 ± 0.09	2.26 ± 0.30	202 ± 28	4.33 ± 0.16	2.89 ± 0.21	132.84 ± 3.93
Total (female)	22	2.62 ± 0.14	2.23 ± 0.24	205 ± 24	4.28 ± 0.18	2.88 ± 0.21[b]	132.56 ± 3.62
Right (R)	26	2.69 ± 0.25	2.28 ± 0.26	198 ± 24	4.35 ± 0.52	3.02 ± 0.31	132.48 ± 3.81
Left (L)	26	2.64 ± 0.19	2.32 ± 0.29	197 ± 24	4.43 ± 0.35	3.01 ± 0.28	133.04 ± 4.52
Total (R+L)	52	2.66 ± 0.22	2.30 ± 0.27	198 ± 23	4.39 ± 0.44	3.02 ± 0.29	132.76 ± 4.15
CV (%)	10	0.84	1.16	0.87	0.49	0.89	0.45
		P-value					
Sex		0.241	0.124	0.068	0.134	0.005	0.770
Right-left		0.382	0.570	0.835	0.476	0.938	0.645
Sex × R-L interaction		0.767	0.946	0.608	0.905	0.892	0.994

[a, b]: Differences between values marked with different letters in the same column are significant.

measurement (CV = 0.45%), and the external acetabular angle has the highest CV (CV = 2.94%) (Tables 1 and 2).

4. Discussion
There is considerable variation in the radiologic appearance of the normal and dysplastic hip joints in dogs of various breeds. The acetabulum and the femoral head vary in size and shape (20). The relative depth of the acetabulum was greatest in St Bernards and Bernese Mountain dogs. Boxers and Labrador Retrievers had the most shallow and open acetabula. German Shepherds and Rottweilers had somewhat deeper and less open acetabulum than these dogs. (20). Anatomic and mechanical femoral joint angles vary between dog breeds (21). FIA shows a significant difference between Dobermans and Labradors, and between Sivas Kangal and Pointer, Irish Setter, Golden

Table 2. Measurements of the acetabulum.

Parameters	N	ACM°	EAA°	AHI
Male-right	15	43.33 ± 2.97	28.91 ± 5.25	72.15 ± 8.84
Male-left	15	44.75 ± 3.60	27.64 ± 4.08	71.89 ± 6.28
Total (male)	30	44.04 ± 3.32[a]	28.27 ± 4.66	72.02 ± 7.53
Female-right	11	42.98 ± 3.03	28.04 ± 5.04	68.57 ± 8.64
Female-left	11	41.33 ± 2.75	28.59 ± 4.58	72.68 ± 5.92
Total (female)	22	42.16 ± 2.94[b]	28.31 ± 4.71	70.62 ± 7.53
Right (R)	26	43.18 ± 2.94	28.54 ± 5.08	70.64 ± 8.77
Left (L)	26	43.3 ± 3.64	28.04 ± 4.24	72.23 ± 6.02
Total (R+L)	52	43.24 ± 3.27	28.29 ± 4.63	71.43 ± 7.49
CV(%)		1.46	2.94	0.90
		P-value		
Sex		0.038	0.038	0.513
Right-left		0.895	0.895	0.368
Sex × R-L interaction		0.087	0.087	0.307

[a, b]: Differences between values marked with different letters in the same column are significant.

Retriever, German Shepherd, Doberman, and Labrador (6). The SKD is also known as a breed predisposed to CHD (1,2) and epiphysiolysis of the femoral head, and fractures and dislocations of the hip joint are frequently observed. In humans, some radiographic measurements of the proximal femur were found correlated with hip fracture risk (22) and ethnicity (17). Although there are some studies that highlight the differences between breeds (21) or breed-specific measurement values in dogs (23), data on measurements of the proximal femur and acetabulum are relatively limited and not enough to classify hip status according to the structure of the proximal femur and acetabulum. However, none of these studies before the present study mentioned the SKD.

Although there is no report about HAL in dogs, there are many studies in human medicine and it has been suggested that HAL is greater in patients with intertrochanteric fractures than control patients (22). Pulkkinen et al. (9) reported the HAL in healthy people as 104.9 ± 7.9 mm. In our study, the HAL in healthy SKDs was found to be statistically greater in males (80.3 ± 8.2 mm) than females (74.7 ± 4.0 mm) (P < 0.01). Considering the relationship between HAL and hip fractures in humans, it may be helpful to determine the normal values in certain breeds and evaluate whether any relationship consists between HAL and different hip pathologies in dogs.

The relationship between TW and trochanteric bursitis and greater trochanteric pain in humans was reported (24). In dogs, chronic calcification of this bursa is often seen radiographically but usually does not cause any clinical problems (25). TW in healthy SKDs was 43.9 ± 4.4 mm for both sexes and it was greater in males than females, but this difference was not statistically significant. This parameter in healthy humans was measured as 52.6 ± 3.4 mm (18). However, size and position of the greater trochanter are breed-dependent (26). Therefore, further investigation into determining this parameter for a certain breed and searching for its relation with hip joint pain in dogs is important.

Palierne et al. (18) reported the FSD, HD, and FNL in dogs as 15.9 ± 5.66 mm, 19.7 ± 4.48 mm, and 18.7 ± 4.57 mm, respectively. Sarierler et al. (27) measured FSD of 19.47 ± 2.18 mm, HD of 17.71 ± 1.31 mm, and ND of 15.64 ± 1.37 mm. The HD and ND obtained from our study, 26.6 ± 2.2 mm and 23.0 ± 2.7 mm, respectively, are greater than those of the two studies mentioned above, which did not include the Sivas Kangal (18,27). However, they are close to results of another study, which reported that the HD was 24.95 ± 2.04 mm and the ND was 21.93 ± 3.69 mm for the Sivas Kangal (28), suggesting that breed standards can be developed with more data. The FSD obtained from our study was significantly greater in male dogs (31.1 ± 3.1 mm) than females (28.8 ± 2.1 mm) (P < 0.01). Pulkkinen et al. reported that the FSC was 7.1 ± 1.1 mm in healthy humans, and this parameter is significantly related to fracture cases (9). We measured an FSC of 3.7 ± 0.8 mm in SKDs.

In our study, because of the difficulties in determining the femoral neck length exactly on radiographs in dogs, two different FNALs (a and b) were measured instead of
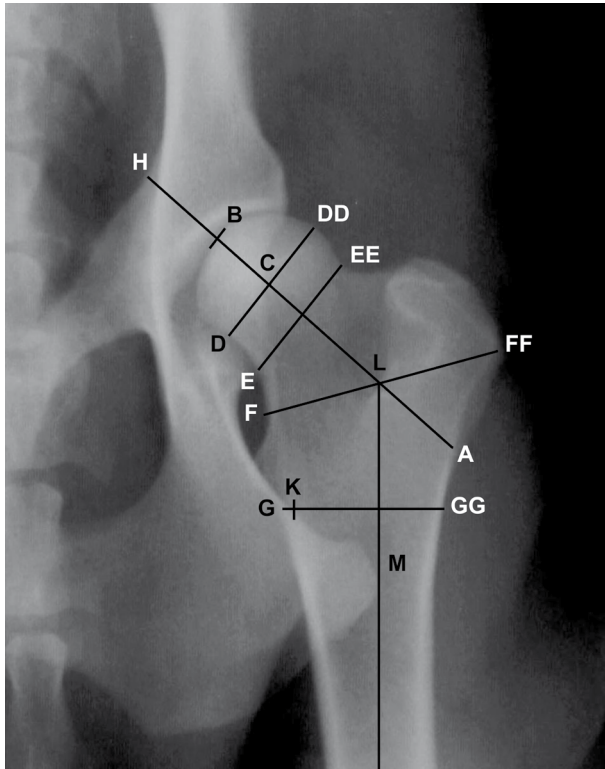
Figure 1. Proximal femoral measurements (9). HAL: The distance between A and H, along the femoral neck axis, defined as the length from junction of femoral neck axis and lateral aspect of the greater trochanter to the pelvis); FNALa, the distance between A and B (length along the femoral neck axis from junction of femoral neck axis and lateral aspect of the greater trochanter to the caput femoris) and FNALb, the distance between A and C (length along the femoral neck axis from junction of femoral neck axis and lateral aspect of the greater trochanter to the center of the caput femoris); AW, the distance between B and H; FSC, cortical thickness at the level G-GG line (just below the trochanter minor and perpendicular to the femoral diaphysis); HD, the distance between D and DD (at the intersection point of the femoral head center and femoral neck axis and perpendicular to the femoral neck axis; ND, the distance between E and EE (the shortest distance within the femoral neck perpendicular to the femoral neck axis); TW, the distance between F and FF (between just above the trochanter minor and the most lateral point of the trochanter major); FSD, the distance between G and GG (just below the trochanter minor and perpendicular to the femoral diaphysis); FIA, the angle of CLM points; K, cortical thickness of femoral diaphysis along the G-GG line; L-M, axis of the femoral diaphysis.

Figure 2. Head-neck index of Heyman and Herndon (a/b × l00; a: total length of femoral head and neck, b: femoral neck width at the narrowest point) (8).

the femoral neck length. It was reported that FNALa and FNALb in humans are 90.3 ± 6.2 mm and 71.1 ± 5.3 mm, respectively (16), and FNALa and FNALb in crossbreed dogs are 40.18 ± 2.62 mm and 31.93 ± 2.12 mm, respectively (27). In our study, male dogs had significantly higher FNALa (64.0 ± 5.5 mm) and FNALb (50.9 ± 4.7 mm) than females (60.9 ± 2.7 mm and 47.8 ± 3.1 mm, respectively).
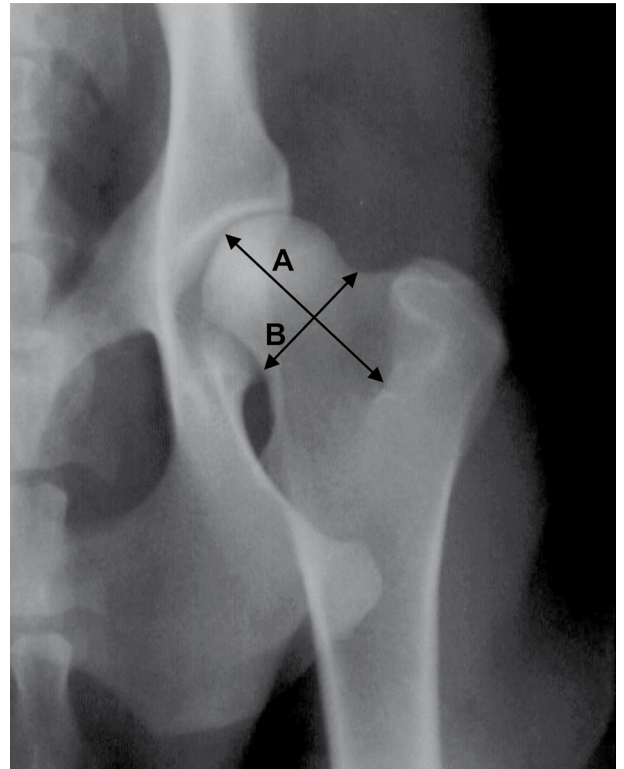
FSD and FNAL (a and b) were also higher than the values published by Sarierler et al (27). However, it was thought that the greater measurements could be accepted as normal for a large dog breed such as the Sivas Kangal compared to crossbreeds. Therefore, it would be useful to determine these parameters in small, medium, and large breed dogs, even based on the breed.

Normal values of the HNI are between 150 and 190 for human (8), and we measured this as 198 ± 23 for SKDs. This parameter in humans was found to be related to femora acetabular impingement, which is caused by reduced femoral anteversion or an osseous bump deformity on the femoral head-neck junction and could be normalized with surgical correction (29). In line with human studies, whether this parameter is related to degenerative changes in the hip joint of dogs or not needs to be investigated.

It was reported that the AW of a healthy human is 15.1 ± 2.8 mm (9), and there was no information about the effect of sex. If sex is not taken into account, the AW was measured as 15.2 ± 3.3 mm in our study, but it was significantly higher (P < 0.01) in males (16.2 ± 3.5 mm) than in females (13.7 ± 2.4 mm).

The acetabular angle, which is derived from the ACM angle of Idelberger and Frank, is the measure of the acetabular depth that is practically invariant with pelvic
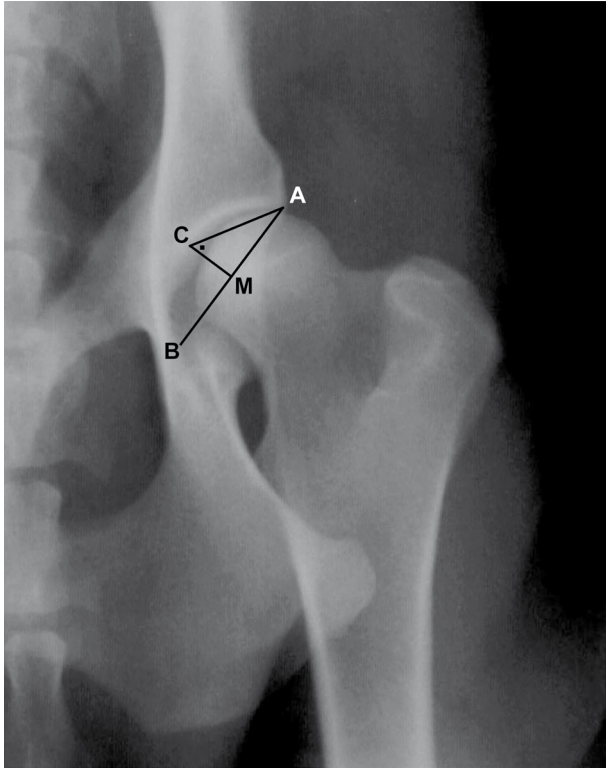
Figure 3. Acetabular angle (angle of ACM points: cranial rim (A) and caudal rim (B) of the acetabulum, M: midpoint of the A-B line, C: intersection point of the perpendicular line to A-B line from M point with acetabulum) (8).
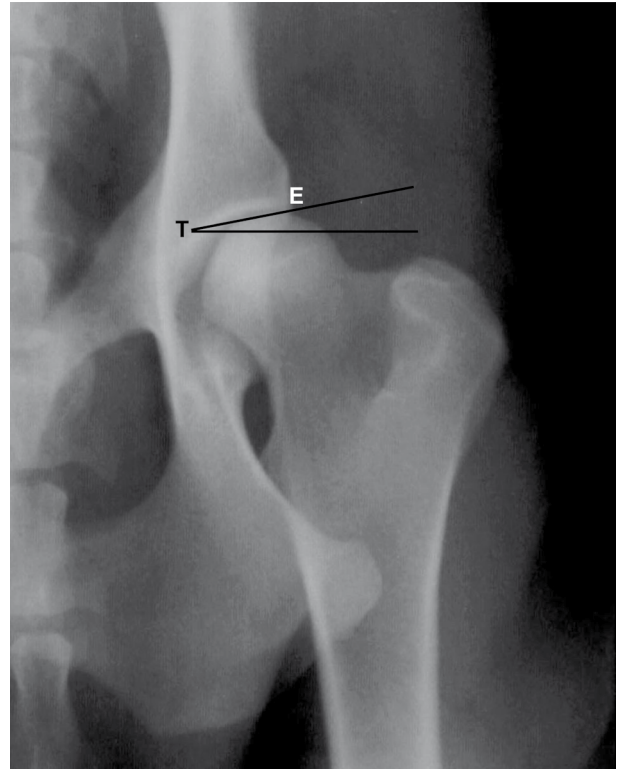
Figure 4. EAA angle (the angle between a line that is drawn between the most lateral point (E) and most medial weight-bearing point (T) of the acetabulum and a second line drawn horizontally from the T point (Delanuay et al.,1996).

rotation, pelvic tilt, and age (9). Idelberger and Frank reported a range of 40–50° for this angle of a normal hip, and the angle exceeds 50° and may reach 74° in dysplastic hips (8). The values (43.24 ± 3.27°) from our study, measured regardless of sex, were consistent with those reported in humans. However, the ACM was greater (P < 0.05) in males (44.04 ± 3.32°) compared to females (42.16 ± 2.94°). This angle actually measures the depth of the acetabulum, and it tells us whether it is shallow or not. Although this angle was not studied previously in dogs, we think that its assessment in both healthy and dysplastic dogs, and also in different breeds, may be helpful in the diagnosis and planning of treatment. However, further studies are needed.

The HTE angle, which is used to evaluate the acetabular roof's orientation at the coronal plan and lateral coverage level of the femoral head in humans, is 10° or lower for healthy humans. A higher HTE is observed mostly in cases of acetabular dysplasia (11). In this study, we named the angle as EAA, derived from the HTE angle. In dogs, there are no data on this parameter. In our study, this angle was found to be 28.29 ± 4.63° in healthy SKDs, which is higher than the HTE angle in humans, and it showed no

sex differences. Since no additional radiography from the standard hip-extended position is required to measure the HTE angle, it was found to be practical.

The AHI measures the percentage of the femoral head surface that is covered by the acetabulum, and this index is lower in dysplastic humans (19,27). The AHI in healthy SKDs was found to be 71.43 ± 7.49%, and there was no significant difference between males and females.

The angle of the femoral neck with the femoral diaphysis, called the cervico-diaphyseal angle, neck angle, neck-shaft angle, and inclination angle, is constant from birth through all ages of development and is varied between 130° and 148° based on different measurement techniques in dogs (13,14,21). In this study, we used the symax-based method (15) for measurement of the femoral inclination angle. Sarierler (6) reported the inclination angle in the Sivas Kangal (Anatolian Karabash) as 138.60 ± 1.29°, which was measured by the symax-based method. In previous studies that used the symax-based method, the FIA was reported as 130.54 ± 0.31° (15), 133.48 ± 4.69° (30), and 127.63° (16) in different breeds. Sarierler (6) reported that age and sex did not affect the femoral neck angle, but there were significant differences (P < 0.001) between some breeds,
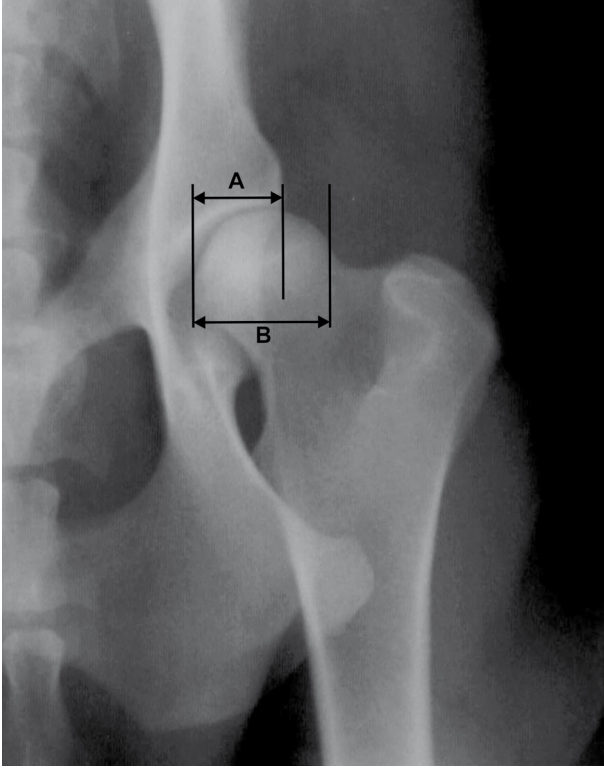
Figure 5: Acetabulum-Head index (A; the distance between a vertical line passing from the most medial point of the femoral head and a vertical line passing from the lateral of the acetabulum, B; the distance between the vertical lines passing from most medial and lateral points of the femoral head, AHI: A/B x 100) (12).

especially between the Anatolian Karabash and six other breeds, Pointer, Irish Setter, Golden Retriever, German Shepherd, Doberman, and Labrador. The FIA values of males (132.91 ± 4.55°, ranging from 125.2° to 140.9°) and females (132.56 ± 3.62°, ranging from 126.7° to 139.1°) obtained in this study are consistent with the literature (6,14,15). Studies on dogs about FIA remain mostly limited to investigating whether there is a relationship between CHD and FIA (6,10,14). Although a greater FIA was found in humans related to intertrochanteric fracture (22), there are no studies investigating the relationship between FIA and other hip and proximal femur diseases in dogs, which is another subject waiting for investigation.

In conclusion, in this study, normal ranges in healthy SKDs of proximal femoral and acetabular parameters related to certain hip joint pathologies in humans were presented. Some of these data have never been studied in dogs before, especially in the Sivas Kangal. Although the small number of cases restricted the ability to draw a clear-cut conclusion, it is expected that these data will provide a significant contribution to the literature and also may be useful for future studies to compare this breed with others. Further studies are needed to determine whether any relationship between these parameters and different hip pathologies exist or not.

Acknowledgment

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