Sağlıklı Alman Çoban Köpeklerinde Pelvis Geometrisinin Ventro-Dorsal Pozisyonda Röntgen Çekimlerinde İncelenmesi

Examination of Pelvic Geometry in Healthy German Shepherd Dogs in Ventro-Dorsal Position X-Rays

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ÖZ

Amaç: Bu çalışma, sağlıklı Alman Çoban köpeklerinde pelvis geometrisinin ventro-dorsal pozisyonda röntgen çekimleriyle incelenmesini amaçlamaktadır. **Gereç ve Yöntem:** Çalışmada, 12 dişi ve 12 erkek olmak üzere toplam 24 adet sağlıklı Alman Çoban Köpeğinin pelvik ve femoral morfometrik ölçümleri değerlendirilmiştir. Bunun için köpeklerin önce klinik muayene testleri yapıldı, sağlıklı olarak geçemeyen köpekler çalışma bünyesinden çıkartıldı. Sağlıklı kabul edilen vakalar Fédération Cynologique Internationale (FCI) standartlarında kalça skorlaması yapmak üzere simetrik ventro-dorsal pelvis röntgeni çekildi. **Bulgular:** Elde edilen bulgular, cinsiyetler arasında özellikle sol iliak uzunluk (dişilerde 100,35±2,25, erkelerde 105,68±6,65), sağ iliak uzunluk (dişilerde 101,28±2,38, erkelerde 106,41±7,78), sol femur eğim açısı (dişilerde 121,83±2,69, 124,66±2,90) gibi parametrelerde anlamlı farklılıklar olduğunu göstermiştir. Erkek köpeklerde bu ölçümlerin dişilere göre daha yüksek olduğu belirlenmiştir. Buna karşın, sağ ve sol Norberg açıları sırasıyla (dişilerde 103,83±2,91, erkeklerde 103,16±2,36) ve (dişilerde 104,91±2,67, erkeklerde 104,58±3,08), gibi kalça displazisi ile ilişkili parametrelerde cinsiyetler arasında anlamlı bir fark gözlenmemiştir. **Sonuç:** Çalışma, pelvik morfometrik ölçümlerin cinsiyete bağlı farklılıklarını ortaya koyarken, bu verilerin kalça displazisinin değerlendirilmesinde tamamlayıcı bir yöntem olarak kullanılabileceğini öne sürmektedir. Radyografik görüntüleme ve dijital ölçüm teknikleri, pelvik yapıların değerlendirilmesinde güvenilir ve tekrarlanabilir sonuçlar sunmuştur. Ancak, çalışmanın sınırlı örneklem büyüklüğü ve tek bir ırka odaklanması, bulguların genellenebilirliğini kısıtlayabilir.

ABSTRACT

Objective: This study aims to examine the pelvic geometry of healthy German Shepherd dogs through ventro-dorsal radiographs. **Materials and Methods:** In the study, pelvic and femoral morphometric measurements of a total of 24 healthy German Shepherd Dogs, 12 females and 12 males, were evaluated. For this purpose, the dogs were first subjected to clinical examination tests, and the dogs that did not pass healthily were removed from the study. In cases considered healthy, a symmetrical ventro-dorsal pelvis x-ray was taken to perform hip scoring according to Fédération Cynologique Internationale (FCI) standards. **Results:** The findings indicate that there were significant differences between sexes in certain parameters, particularly left ilial length (100.35 ± 2.25 in females, 105.68 ± 6.65 in males), right ilial length (101.28 ± 2.38 in females, 106.41 ± 7.78 in males), and left femoral inclination angle (121.83 ± 2.69 in females, 124.66 ± 2.90 in males). These measurements were found to be higher in males compared to females. In contrast, no significant differences were observed between sexes in parameters related to hip dysplasia, such as the right and left Norberg angles (103.83 ± 2.91 in females, 103.16 ± 2.36 in males) and (104.91 ± 2.67 in females, 104.58 ± 3.08 in males), respectively. **Conclusion:** The study highlights the role of pelvic morphometric measurements in identifying gender-related structural differences and suggests their potential as complementary tools in assessing hip dysplasia. Radiographic imaging and digital measurement techniques provided reliable and reproducible results for evaluating pelvic structures. However, the study's limited sample size and focus on a single breed may restrict the generalizability of the findings.

GİRİŞ

Canine hip dysplasia (CHD) is a developmental disorder of the coxofemoral joint characterized by laxity, structural incongruence, and secondary osteoarthritis affecting one or both hip joints. The condition has a polygenic and multifactorial etiology and has challenged veterinarians and researchers since it was first described in the 1930s.[1,2] Environmental factors such as nutrition, exercise, and the dynamics of endochondral ossification further modulate the expression and severity of CHD.[3,4]

Reported prevalence ranges from 1% to 80% among breeds, with large-bodied or brachycephalic dogs and those with relatively high body length-to-height ratios being particularly affected.[5-7]

Radiography remains the primary imaging modality for diagnosing CHD in dogs. Standardized ventro-dorsal pelvic views enable the assessment of acetabular depth, femoral head coverage, joint congruence, and secondary degenerative changes, thereby supporting early diagnosis and follow-up. Radiographic parameters such as the Norberg angle and pelvic angular measurements form the basis of widely used grading systems, including OFA and FCI, and they play a crucial role in breeding programs aimed at reducing the hereditary transmission of CHD.[8,9]

Joint degeneration in CHD has been attributed to joint laxity, abnormal loading, and irregular or delayed endochondral ossification. Partially ossified hip structures may be particularly vulnerable to mechanical stress, resulting in deformation of the acetabular rim, femoral head, and surrounding trabecular architecture.[10,11] Affected joints frequently exhibit synovial inflammation, cartilage erosion, osteophyte formation, and subchondral bone remodeling.[5] Subluxation of the femoral head and delayed ossification of the craniodorsal acetabular margin can be observed from as early as 8-12 weeks of age, while cartilage degeneration and capsular thickening become evident in the following months.[7,12] Despite these lesions, clinical signs can vary widely between individuals.

Continuous efforts to characterize hip morphology and joint alterations have contributed to more refined phenotypic classifications of CHD and to strategies for earlier, more targeted interventions.[13,14] Pelvic morphometric data in clinically healthy dogs of specific breeds are essential for establishing reference values that may distinguish normal variation from early pathological change.

The present study aimed to determine physiological pelvic bone parameters in clinically healthy German Shepherd dogs presented for hip scoring. Symmetrical ventro-dorsal pelvic radiographs were obtained, and a series of morphometric measurements were evaluated to describe sex-related differences and provide reference data for orthopedic assessment.

MATERIALS and METHODS

This study was conducted with the approval of the Balıkesir University Local Ethics Committee for Animal Experiments (Approval No: 2024/6-3; Date: 04.07.2024).

The study material consisted of German Shepherd dogs aged 12-18 months, intact, and considered clinically healthy, which were presented to the Balıkesir University Faculty of Veterinary Medicine Animal Hospital and the PetX Clinic Veterinary Practice. Following physical examination and radiographic evaluation, hip scoring was performed according to the FCI criteria, and dogs classified as grades A or B were included in the study. A total of 29 dogs met the initial inclusion criteria.

Of these, 17 were female and 12 were male. One female dog was excluded due to a suspicious Ortolani test result during the clinical assessment. Additionally, ventro-dorsal hip radiographs of four other female dogs were deemed asymmetric or unsuitable for evaluation; thus, these individuals were also excluded. Consequently, the study was completed with 24 dogs (12 females and 12 males) that met all required criteria. For each included dog, a complete physical examination was performed, followed by ventro-dorsal pelvic radiography under general anesthesia, during which pelvic measurements were obtained. After adequate muscle relaxation was achieved, the animals were initially positioned in lateral recumbency and subsequently placed in dorsal recumbency on the radiographic table. To prevent positioning errors, the hind limbs were extended caudally and gently rotated medially to ensure optimal alignment of the femoral heads. Radiographs were acquired only when both femurs were parallel to each other and the spacing between them was symmetrical (Table 1).[15] The radiographs were obtained at 72 kV, 1.6 mAs, and a focal distance of 100 cm.

Table 1. Information on the dogs used in the study.

Gender	Total Number	Eliminated in Clinical Examination	Radiography not Appropriate	Included in the Study
Female	17	1	4	12
Male	12	0	0	12
Total	**29**	**1**	**4**	**24**

Clinical Examination and Evaluation

After completion of the clinical examination, anesthesia was induced to ensure adequate muscle relaxation for orthopedic testing and radiographic positioning. The Barlow maneuver was performed with the dogs in lateral and dorsal recumbency; with the femur held in adduction, proximal pressure was applied, and luxation or subluxation of the femoral head was recorded as a positive sign. Hips with a positive Barlow test were then evaluated using the

Ortolani maneuver, in which the femur is abducted while proximal pressure is maintained; palpable reduction of a luxated or subluxated femoral head was considered a positive Ortolani sign.[16] Dogs with positive or inconsistent test results were excluded.

Radiographic Measurements

Thirteen pelvic measurements were obtained from the ventro-dorsal pelvic radiographs. These included ilial length, ischial length, ischial tuberosity length, width of sacrum, pelvic diameter, pelvic symphysis length, cranial ilial aperture, os coxa length, internal pelvic angle, femoral inclination angle, Norberg angle, obturator foramen length and width, and the cranial ramus/corpus length of the pubic bone. All linear measurements were recorded in millimeters. All measurements were performed by the investigator in a blinded manner. Pelvic measurements and subsequent analyses were conducted on the radiographic images using AutoCAD 2025 (Autodesk Inc., San Rafael, CA, USA).[17] In each radiograph, the width of the metal marker placed as a reference was used to standardize all measurements across the images.

The Norberg angle (NA) was measured for both hips, and the mean value was used for evaluation. To reduce the influence of outliers, measurements below 75° were adjusted to 75°. Based on the mean NA, hip status was classified as normal (>105°), borderline (95°-105°), or dysplastic (<95°). The femoral inclination angle was measured separately for each femur, and the average was used for analysis.

Ilial length was defined as the distance between the most cranial point of the ilium and the dorsal acetabular rim. Ischial length was measured from the most caudal point of the ischium to the caudal acetabular rim. Ischial tuberosity length was calculated as the distance from the most lateral point of the ischial tuberosity to the nearest point on the midline. Width of sacrum was determined by measuring the widest points of the sacrum, whereas pelvic diameter was defined as the maximum width of the pelvic inlet. Pelvic symphysis length was measured between the most cranial point of the pubis and the most caudal point of the ischium. Cranial ilial aperture was defined as the distance between the most cranial points of both ilium. Os coxa length was measured as the straight distance from the acetabulum to the most caudal border of the ischium. The internal pelvic angle was calculated based on the medial surfaces of the ilium. The femoral inclination angle was measured as the angle between the long axis of the femur and the acetabulum.[18]

The Norberg angle was measured on ventro-dorsal radiographs as the angle formed between a line connecting the centers of both femoral heads and a second line drawn from the center of each femoral head to the intersection of the dorsal rim and craniolateral margin of the acetabulum (Figure 1).[19]

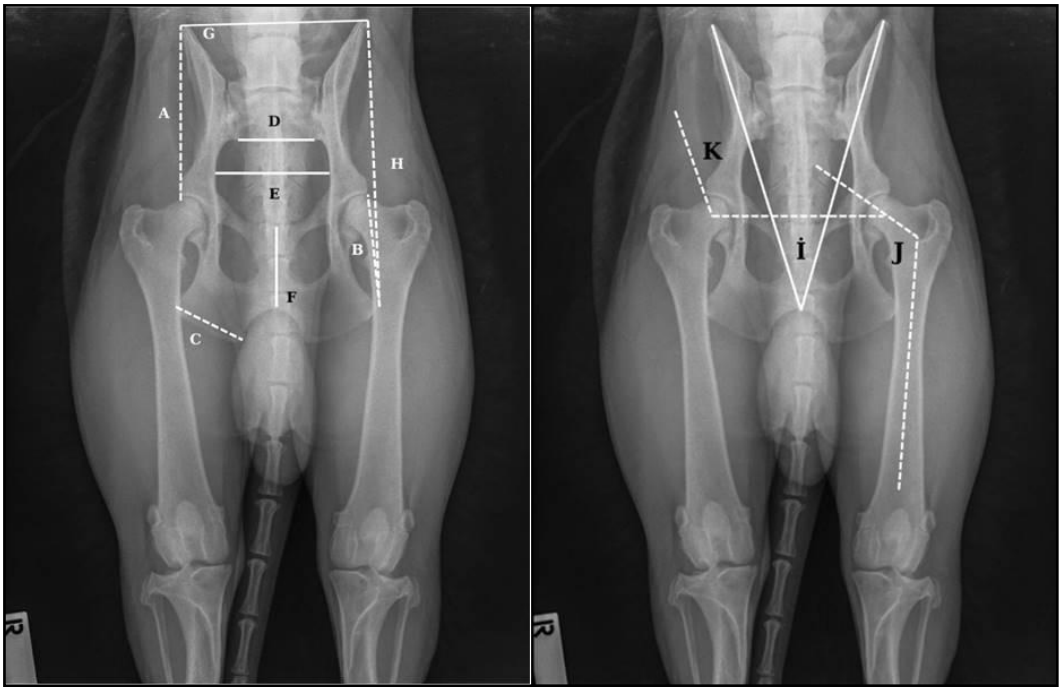

Figure 1. Morphometric parameters and angles evaluated as the principal components of the pelvic bone. (A) Ilial length, (B) Ischial length, (C) Ischial tuberosity length, (D) Width of sacrum, (E) Pelvic diameter, (F) Pelvic symphysis length (pubis-to-ischium distance), (G) Cranial ilial aperture, (H) Coxal bone length, (I) Pelvic internal angle, (J) Femoral inclination angle (measured bilaterally), and (K) Norberg angle. (Case No: 6).

For the obturator foramen measurements, the major axis (line A) was defined as the longest distance extending from the craniolateral aspect to the caudomedial aspect of the foramen. A minor axis (line B) was then drawn perpendicular to line A at its midpoint and was recorded as the shortest diameter of the foramen.[20]

For measurements of the cranial ramus and body of the pubic bone, one circle (A) was placed over the narrow portion of each pubic ramus, and a second circle (B) was positioned proximally to include the cranial pubic tubercle and the pubic symphysis. The medial borders of the obturator foramen were required to be tangent to circle B. The centers of circles A and B were used as reference points to guide the pubic alignment. A reference line (T line) was then drawn from the center of circle B (pubic symphysis) to the midpoint of the acetabular fossa, passing through the center of circle A (pubic ramus) on both sides (Figure 2).[20]

Figure 2. Measurements of the long (L) and short (M) axes of the foramen obturatum, and the cranial ramus and corpus dimensions of the pubic bone (T). (Case No: 6)

Statistical Analysis

Descriptive statistics (mean±SD) were calculated for all continuous variables. Normality was assessed using the Shapiro-Wilk test. Sex-related differences were evaluated by analysis of variance (ANOVA). Statistical significance was set at $p<0.05$. All analyses were performed using SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA).

RESULTS

In the overall sample, the mean ilial lengths were 103.84±6.21mm on the right side and 103.02±5.56mm on the left. The mean ischial lengths were 64.52±4.35mm on the right and 63.94±4.29mm on the left. The average width of sacrum for all individuals was 46.59±2.77mm, while the mean pelvic diameter was 65.82±3.57mm (Table 2). Sex-based comparisons showed that ilial lengths were greater in males (right: 106.41±7.78mm; left: 105.68±6.65mm) than in females (right: 101.28±2.38mm; left: 100.35±2.25mm). Similarly, males exhibited larger width of sacrum (47.65±3.12mm) and pelvic diameter (65.45±4.80mm) values compared with females (45.54±1.97mm and 66.18±1.82mm, respectively). The internal pelvic angle measured 34.41±1.83° in males and 34.83±1.85° in females. Norberg angles for the right and left hip joints were 103.16±2.36° and 104.58±3.08° in males, and 103.83±2.91° and 104.91±2.67° in females, respectively. These values fell within acceptable limits for non-dysplastic hips in both sexes. Measurements of the major and minor axes of the obturator foramen, as well as pubic bone parameters, were generally higher in males. The cranial ramus length of the pubis on the right side was similar between sexes (males: 41.30±3.79mm; females: 41.39±2.89 mm). On the left side, the values were 39.19±1.87mm in males and 38.95±2.38mm in females (Table 2). Statistically significant sex-related differences were observed in ilial length (right: $p=0.048$; left: $p=0.020$), ischial length (right: $p=0.046$; left: $p=0.009$), ischial tuberosity length (right: $p<0.001$; left: $p<0.001$), coxal bone length (right: $p=0.028$; left: $p=0.007$), and left femoral inclination angle ($p=0.021$). These findings indicate that male dogs have greater pelvic bone lengths and higher left femoral inclination angles compared with females.

In contrast, no significant sex differences were detected for width of sacrum ($p=0.061$), pelvic symphysis length ($p=0.090$), cranial iliac opening ($p=0.256$), pelvic diameter ($p=0.629$), pelvic inlet

angle (*p=0.585*), Norberg angles (right: *p=0.545*; left: *p=0.780*), or obturator foramen measurements (*p>0.05*). Similarly, the cranial pubic ramus length (right: *p=0.945*; left: *p=0.789*) did not differ significantly between sexes (Table 2).

Table 2. Measurements obtained from ventro-dorsal radiographic evaluations of the dogs (overall, male, and female mean ± standard deviation) and comparison results between male and female dogs (n = 24). *P* value *<0.05.*

Parameter	Female–Male Mean ± SD	Female Mean ± SD	Male Mean ± SD	t	*P*
Ilial length (right)	103.84±6.21	101.28±2.38	106.41±7.78	-2.,185	*0.048*
Ilial Length (Left)	103.02±5.56	100.35±2.25	105.68±6.65	-2.626	*0.020*
Ischial Length (Right)	64.52±4.35	62.73±2.13	66.32±5.28	-2.182	*0.046*
Ischial Length (Left)	63.94±4.29	61.68±1.99	66.20±4.85	-2.984	*0.009*
Ischial Tuberosity Length (Right)	47.09±2.54	45.31±1.,29	48.86±2.23	-4.771	*0.000*
Ischial Tuberosity Length (Left)	46.71±2.79	44.96±1.31	48.47±2.80	-3.921	*0.001*
Width of Sacrum	46.59±2.77	45.54±1.97	47.65±3.12	-1.978	*0.061*
Pelvic Diameter	65.82±3.57	66.18±1.82	65.45±4.80	0.494	*0.629*
Pelvic Symphysis Length	47.79±5.07	46.00±2.74	49.59±6.27	-1.811	*0.090*
Cranial Ilial Aperture	108.24±9.28	106.03±5.65	110.45±11.73	-1.177	*0.256*
Coxa Length (right)	167.65±9.46	163.30±3.00	172.00±11.71	-2.492	*0.028*
Coxa Length (left)	166.46±8.80	161.55±2.54	171.38±10.14	-3.255	*0.007*
Pelvic Inlet Angle	34.62±1.81	34.83±1.85	34.41±1.83	0.554	*0.585*
Femoral Inclination Angle (right)	123.5±2.81	123.08±2.93	123.91±2.74	-0.718	*0.480*
Femoral Inclination Angle (left)	123.25±3.09	121.83±2.69	124.66±2.90	-2.480	*0.021*
Norberg Angle (right)	103.50±2.62	103.83±2.91	103.16±2.36	0.615	*0.545*
Norberg Angle (left)	104.75±2.83	104.91±2.67	104.58±3.08	0.282	*0.780*
Obturator Foramen Major Axis (right)	37.64±3.34	37.27±1.87	38.01±4.42	-0.,539	*0.595*
Obturator Foramen Major Axis (left)	37.47±3.17	37.06±1.77	37.88±4.19	-0.627	*0.537*
Obturator Foramen Minor Axis (right)	23.20±2.75	23.06±1.87	23.34±3.51	-0.246	*0.808*
Obturator Foramen Minor Axis (left)	21.15±1.90	20.96±1.48	21.,33±2.30	-0.469	*0.644*
Pubic Bone Cranial Ramus Length (right)	41.34±3.30	41.39±2.89	41.30±3.79	0.070	*0.945*
Pubic Bone Cranial Ramus Length (left)	39.07±2.10	38.95±2.38	39.19±1.87	-0.271	*0.789*

DISCUSSION

In this study, pelvic and femoral morphometric measurements were evaluated in a total of 24 healthy German Shepherd dogs, including 12 females and 12 males. The findings demonstrate that radiographic pelvic measurements are effective in identifying sex-related morphological differences in dogs. Notably, males exhibited significantly greater values for ilial length, ischial length, ischial tuberosity length, coxal bone length, and the left femoral inclination angle. These results indicate that the pelvic structure shows a clear morphological association with sex, particularly in terms of bone size and linear dimensions. In a study conducted on 34 adult dogs, male individuals generally had larger pelvic measurements than females, although statistically significant differences were limited to distances between the anterior inferior iliac spine and the pubic tubercle.[21] Likewise, an osteometric analysis in Retriever breeds showed that males had significantly higher values for six pelvic parameters; however, these differences were not considered sufficient for definitive sex determination.[22] Conversely, some studies have reported minimal or no sex-related differences. For example, a computed tomography pelvimetry study in German Shepherd dogs found no significant correlation between pelvic measurements and body weight, age, or sex. Additionally, three-dimensional geometric morphometric analyses across various breeds indicated that male dogs exhibited greater pelvic shape variation than females, with a tendency toward right-sided asymmetry.

Collectively, these findings suggest that pelvic morphology in dogs is influenced by sex, breed characteristics, and individual variation. Therefore, a comprehensive and multidimensional approach is necessary when interpreting pelvic measurements in clinical and research settings.

The literature consistently reports that pelvic morphometric measurements are frequently employed to identify sex-related differences in dogs. In particular, the lengths of major pelvic bones such as the ilium and ischium have been shown to be greater in males than in females, as demonstrated in several previous morphometric studies.[20,23] This

pattern is generally attributed to the larger body mass and more robust pelvic development typically observed in male dogs. Similarly, the more prominent ischial tuberosity measurements recorded in males have been associated with functional differences in muscular attachment sites. The findings of the present study are in agreement with these previously published observations.

In the current study, Norberg angles were comparable between sexes. This suggests that hip joint conformation may be less influenced by sex compared with other pelvic structures. The Norberg angle is widely recognized as a key parameter in the radiographic assessment of hip dysplasia, with values exceeding 105° generally considered indicative of normal hip conformation.[24,25] In the present dataset, the mean Norberg angles measured in females (103.83° for the right hip and 104.91° for the left) and males (103.16° and 104.58°, respectively) remained within ranges considered acceptable and outside the threshold for moderate to severe dysplasia. However, it should be noted that these values do not entirely rule out mild dysplastic changes, and individual variation must be taken into account.

Pelvic inlet angle measurements were similar between sexes, with mean values of 34.41° in males and 34.83° in females. These findings indicate that sex-related variation in pelvic angular morphology is minimal. Although previous studies have proposed that pelvic inlet angle may play a role in the development of hip dysplasia, consensus on this matter remains limited.[26,27] However, this implies that the pelvic inlet angle can be evaluated using a breed-specific reference range, simplifying the diagnostic criteria for dysplasia risk regarding this parameter.

Similarly, measurements of the major and minor axes of the obturator foramen, as well as those of the pubic bone, demonstrated comparable values between males and females. For instance, the cranial ramus of the pubis measured 41.30mm (right) and 39.19mm (left) in males, and 41.39mm (right) and 38.95mm (left) in females. These results suggest that such parameters are less useful for sex differentiation and are more reflective of individual anatomical variation, as previously noted.[20] Also from a clinical perspective, this lack of dimorphism is advantageous. The pubic osteotomy can be performed using standard anatomical landmarks and surgical margins applicable to both sexes. Therefore, these parameters, serve as reliable, sex-independent anatomical constants for surgical orientation.

There are conflicting reports about the role of the femoral inclination angle in hip dysplasia. It has been reported that this angle can increase in dysplastic dogs, leading to instability and subluxation, and that surgical interventions such as intertrochanteric osteotomy are required to correct this condition.[28] Another study reported no difference between dysplastic and non-dysplastic German Shepherd dogs and that it was not affected by age or sex.[29] This discrepancy in the literature may cause from the severity of the disease in the studied populations; while femoral inclination angle may remain stable in mild laxity, significant structural alterations like Coxa Valga in advanced stages. This difference may facilitate the selection of special osteotomy plates with larger angles, especially in TPO/DPO surgeries, due to the increased femoral incineration angle.[28] In the present study, a significant difference was identified only in the left femoral inclination angle (*p=0.021*), with males exhibiting a mean value of 124.66° and females 121.83°. This finding suggests that pelvic geometry may contain gender-specific variations. Therefore, while this parameter alone is not sufficient for hip dysplasia, it should be considered gender-specific rather than a standard value in surgical plans aimed at correcting the femoral angle. No statistically significant difference was found between sexes in right femoral inclination angles. Although this finding is consistent with previous studies, the difference observed in the left femoral inclination angle supports reports in the literature indicating that this measurement is highly sensitive to radiographic positioning.[15,29]

The use of only healthy dogs in our study can be considered a limitation in terms of the direct applicability of the data obtained for the diagnosis of hip dysplasia. However, before any pathology can be identified, it is crucial to first clarify what constitutes normal and how this normal is influenced by factors such as gender.[30] Without establishing these baseline values in the healthy population, it is difficult to distinguish whether the pathological changes observed in dysplastic dogs are a consequence of the disease or a predisposing feature.[31] Therefore, the potential of the data presented in this study will be better demonstrated through future comparative studies with dysplastic cases.

The use of standardized measurement protocols, combined with digital radiography and AutoCAD-based analyses, strengthened the accuracy and reliability of the results. However, certain limitations should be acknowledged, including the relatively small sample size and the exclusive evaluation of a single breed. Future studies incorporating larger cohorts, multiple breeds, and varied age groups will be essential to improve the generalizability of these findings.

Diagnostic measurements such as the Norberg angle are generally applicable between the sexes, but pelvic architecture has been shown to exhibit significant sexual differences. Male German Shepherds, in particular, exhibited greater ilial length and femoral inclination angles than females. Clinically, these

findings demonstrate the need for a gender-specific approach to preventive surgeries such as triple and double pelvic osteotomies. Osteotomy line selection and implant sizing should be made with these anatomical differences in mind to ensure optimal biomechanical correction. Normal data in these healthy animals are crucial for distinguishing from pathological changes.

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REFERENCES

1. Ginja M.M.D., Silvestre A.M., Gonzalo-Orden J.M., Ferreira A.J.A.: Diagnosis, genetic control, and preventive management of canine hip dysplasia: A review. Vet. J. 2010, 184(3): 269-276.
2. Schachner E.R., Lopez M.J.: Diagnosis, prevention, and management of canine hip dysplasia: A review. Vet. Med (Auckl). 2015, 6: 181-192.
3. Fries C.L., Remedios A.M.: The pathogenesis and diagnosis of canine hip dysplasia: A review. Can. Vet. J. 1995, 36(8): 494.
4. Krontveit Randi I., Nødtvedt A., Sævik BK., Ropstad E., Trangerud C.: Housing-and exercise-related risk factors associated with the development of hip dysplasia as determined by radiographic evaluation in a prospective cohort of Newfoundlands, Labrador Retrievers, Leonbergers, and Irish Wolfhounds in Norway. Am. J. Vet. Res. 2012, 73(6): 838-846.
5. King M.D.: Etiopathogenesis of canine hip dysplasia, prevalence, and genetics. Vet. Clin. North Am. Small Anim. Pract. 2017, 47(4): 753-767.
6. Wood J.L.N., Lakhani K.H., Rogers K.: Heritability and epidemiology of canine hip-dysplasia score and its components in Labrador retrievers in the United Kingdom. Prev. Vet. Med. 2002, 55(2): 95-108.
7. Kapatkin A.S., Mayhew P.D., Smith G.K.: Genetic control of canine hip dysplasia. Compend. Contin. Educ. Pract. Vet. 2002, 24: 681-686.
8. Zhang Z., Zhu L., Sandler J., Friedenberg S.S., Egelhoff J., Williams A.J., Dykes N.L., Hornbuckle W., Krotscheck U., Moise S., Lust G., Todhunter R.J.: Estimation of heritabilities, genetic correlations, and breeding values of four traits that collectively define hip dysplasia in dogs. Am. J. Vet. Res. 2009, 70(4): 483-492.
9. Kaneene J.B., Mostosky U.V., Miller R.: Update of a retrospective cohort study of changes in hip joint phenotype of dogs evaluated by the OFA in the United States, 1989-2003. Vet. Surg. 2009, 38(3): 398-405.
10. Krotscheck U., Todhunter T.: The pathogenesis of hip dysplasia. In: Bojrab M.J., Monnet E., Editors, Mechanisms of Disease in Small Animal Surgery. 3. Baskı. Teton NewMedia, Florence, 2012, sayfa: 638-647.
11. Todhunter R.J., Zachos T.A., Gilbert R.O., Erb H.N., Williams A.J., Burton-Wurster N., Lust G.: Onset of epiphyseal mineralization and growth plate closure in radiographically normal and dysplastic Labrador Retrievers. J. Am. Vet. Med. Assoc. 1997, 210(10): 1458-1462.
12. Kealy R.D., Olsson S.E., Monti K.L., Lawler D.F., Biery D.N., Helms R.W., Lust G., Smith G.K.: Effects of limited food consumption on the incidence of hip dysplasia in growing dogs. J. Am. Vet. Med. Assoc. 1992, 201(6): 857-863.
13. Barr A.R.S., Denny H.R., Gibbs C.: Clinical hip dysplasia in growing dogs: the long-term results of conservative management. J. Small Anim. Pract. 1987, 28(4): 243-252.
14. Fry T.R., Clark D.M.: Canine hip dysplasia: clinical signs and physical diagnosis. Vet. Clin. North Am. Small Anim. Pract. 1992, 22(3): 551-558.
15. Butler J.R., Gambino J.: Canine hip dysplasia: diagnostic imaging. Vet. Clin. North. Am. Small Anim. Pract. 2017, 47(4): 777-793.
16. Vidoni B., Bauer V., Bockstahler B., Gumpenberger M., Tichy A., Aghapour M.: Early diagnosis of canine hip laxity: correlation between clinical orthopedic examinations and the fcı scoring method in a closed cohort of rottweilers. Animals (Basel). 2021, 11(2): 416.
17. Sahin S., Akata E., Sahin O., Tuncay C., Özkan H.: A novel computer-based method for measuring the acetabular angle on hip radiographs. Acta. Orthop. Traumatol. Turc. 2017, 51(2): 155-159.
18. Fealey M.J., Li J., Todhunter R.J.E., Krotscheck U., Hayashi K., McConkey M.J., Boyko A.R., Hayward J.J., Todhunter R.J.: Genetic mapping of principal components of canine pelvic morphology. Canine Genet. Epidemiol. 2017, 4: 4.
19. Vidoni B., Aghapour M., Kneissl S., Vezzoni A., Gumpenberger M., Hechinger H., Tichy A., Bockstahler B.: Inter-observer agreement in radiographic diagnosis of coxofemoral joint disease in a closed cohort of four-month-old rottweilers. Animals (Basel). 2022, 12(10): 1269.
20. Boiocchi S., Vezzoni L., Vezzoni A., Bronzo V., Rossi F.: Radiographic changes of the pelvis in Labrador and Golden Retrievers after juvenile pubic symphysiodesis: objective and subjective evaluation. Vet. Comp. Orthop. Traumatol. 2013, 26(3): 218-225.
21. Sajjarengpong K., Adirekthaworn A., Srisuwattanasagul K., Sukjumlong S., Darawiroj D.: Differences seen in the pelvic bone parameters of male and female dogs. Thai J. Vet. Med. 2003, 33(4): 55-61.
22. Nganvongpanit K., Pitakarnnop T., Buddhachat K., Phatsara M.: Gender-related differences in pelvic morphometrics of the Retriever Dog breed. Anat. Histol. Embryol. 2017, 46: 51-57.
23. Onar V., Özcan S., Pazvant G.: Skull typology of adult male kangal dogs. Anat. Histol. Embryol. 2001, 30: 41-48.
24. Genevois J.P, Remy D., Viguier E., Carozzo C., Collard F., Cachon T., Maitre P., Fau D. Prevalence of hip dysplasia according to official radiographic screening, among 31 breeds of dogs in France. Vet. Comp. Orthop. Traumatol. 2008, 21(1): 21-24.
25. Smith G.K., Agnello K.A., Karbe G.T., McDonald-Lynch M.B.: Pathogenesis, diagnosis, and control of canine hip dysplasia. In: Tobias K.M., Johnston S.A., Editors, Small Animal Surgical Practices. 1. Baskı. Elsevier, St. Louis, 2011, sayfa: 824-848.
26. Flückiger M.: Scoring radiographs for canine hip dysplasia-The big three organisations in the world. Eur. J. Companion Anim. Pract. 2007, 17(2): 135-140.
27. Brass W.: Hip dysplasia in dogs. J. Small Anim. Pract. 1989, 30(3): 166-170.
28. Güzel Ö., Altunatmaz K.: Canine hip dysplasia and it's treatment using the triple pelvic osteotomy (TPO) method. J. Fac. Vet. Med. Istanbul Univ. 2006, 32(1): 13-21.
29. Sarıerler M.: Comparison of femoral inclination angle measurements in dysplastic and nondysplastic dogs of different breeds. Acta Vet. Hung. 2004, 52(2): 245-252.
30. Mostafa A.A., Berry C.R., Nahla M.A.: Quantitative assessment of hip morphology to enhance the identification of hip dysplasia in German Shepherd Dogs. Am. J. Vet. Res. 2023, 84(3): ajvr.22.09.0165.
31. Gebriel M.E., Fayez F.M., Mostafa A., Nahla M., Tolba A., Shaker N., Aboulela Y.S., Noor N.: Morphometric characterization of normal and dysplastic canine coxofemoral joint using bone specimens, 3D printed models, radiography, and computed tomography. Egypt. J. Vet. Sci. 2025, 1-14.