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Radiographic pelvimetry in Scottish Fold cats: sex-related differences

Osman YILMAZ[1,*], Davut KOCA[2], Talha AVCILAR[3]

[1]Department of Anatomy, Faculty of Veterinary Medicine, Van Yüzüncü Yıl University, Van, Turkiye
[2]Department of Obstetrics and Gynecology, Faculty of Veterinary Medicine, Van Yüzüncü Yıl University, Van, Turkiye
[3]Beta Veterinary Clinic, Bursa, Turkiye

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Abstract: This study was carried out to obtain osteometric measurements of the pelvis of Scottish Fold cats using X-ray images and reveal the biometric differences of these measurement values in terms of sexual dimorphism. Radiographic images of the pelvis in the laterolateral and ventrodorsal direction were used in male and female Scottish Fold cats aged 2–4 years with dystocia and eutocia. The measurements of 18 osteometric parameters and 36 parameters, such as the height/width ratio of the cat pelvis, were taken, and statistical analysis of the measurements was initiated. When the pelvimetric data were examined, it was observed that all of the remaining 16 measurement values, except for inclinatio pelvis and arcus ischiadicus measurement values, were statistically significantly higher in the male cats than in the female cats ($p < 0.05$). Mean height/width ratio measurements in the cats with dystocia were mostly higher (21 parameters out of 36 parameters) than in male cats and cats with eutocia. In general, in the pelvic measurements of both male cats and cats with eutocia and dystocia, there were predominantly positive correlations. However, there were also statistically significant negative correlations. The mean pelvic inlet and outlet area measurement values were calculated as 38.21 ± 0.86 cm^2 and 29.21 ± 1.21 cm^2 in the males, 32.67 ± 0.95 cm^2 and 26.38 ± 0.87 cm^2 in cats with eutocia, and 29.83 ± 1.41 cm^2 and 24.83 ± 1.01 cm^2 in cats with dystocia, respectively. The basic pelvimetric data obtained in Scottish Fold cats in this study will benefit future research focusing on sex determination, breeding management programs for cats, and animal selection and help individuals working in animal clinics and on zooarchaeology.

Key words: Cats, dystocia, eutocia, pelvis, radiographic pelvimetry

1. Introduction

The Scottish Fold cat was first bred by a farmer named William Ross and scientists in Scotland in 1961. In 1966, the Scottish Fold, which distinguishes itself from other cats due to its small and inwardly curved ear structure, was registered by the Governing Council of the Cat Fancy. The Scottish Fold won the Cat Fanciers Association championship in 1978 and, since then, has become one of the most loved and looked after cat breeds. Scottish Fold cats were listed as a separate breed by The International Cat Association (https://www.tica.org/breeds/browse-all-breeds). The cats have rounded bodies, large round eyes, and are middle-sized with thick fur, giving them a stocky look. Their most distinctive feature is that their ears are folded and flat and appear attached to the head [1,2].

Dystocia is the inability to give birth without the need for intervention, whereas eutocia refers to a labor and delivery process that is smooth and uncomplicated [3]. While dystocia is caused by maternal or fetal factors, in some cases, it may be caused by both conditions [4]. Primary and secondary uterine inertia, stenosis of the pelvic canal, malnutrition, metabolic diseases, reproductive anatomical disorders, and parasite infestations can be causes of a difficult maternal birth. Fetal-related causes include fetal anomalies, fetal death, presentation, position, and posture disorders, and causes related to giant offspring (larger than usual). While the incidence rate of dystocia in cats is 3.3%–5.8%, 29.7% of cases within this range are associated with fetal and 67.1% maternal factors [5].

Imaging methods are used in many areas of veterinary medicine, and radiography is critical in the veterinary field [6–8]. Pregnancy examination, especially in surgical cases, is an important diagnostic method frequently used in many birth and gynecological cases, such as uterine infections, genital organ tumors, segmental aplasia, pregnancy pathologies, and dystocia [9,10]. In addition, radiographic examination is crucial in evaluating maternal pelvic morphology, fetal number, size, position, and general abdominal status in difficult deliveries. However, determining the pelvis's dimensions is essential in distinguishing normal and difficult births, depending on race [11].

* Correspondence: osman_40_5@hotmail.com

Pelvimetry is the process of determining pelvic dimensions to prevent various degrees of obstetric complications, usually in the reproductive area. Radiographic pelvimetry, on the other hand, is carried out by radiographic examination of pelvic measurements [7]. In nonhuman primates [12], the common marmoset [13], the *Tamandua tetradactyla* [14], dogs [8,15], the lynx [16], and cats [6,7], radiographic pelvimetry is used to determine pelvic measurements. The shape of the pelvis differs according to the species and between sexes within the same species. Generally, the female pelvis is larger than the male's, and the tubers and protrusions are flatter. Studies have reported that the shape of the pelvis may be a hereditary feature, both maternally and paternally [11]. For this reason, reproductive selection should be made according to both pairs, not just according to female pelvic measurements. This selection may reduce the occurrence of dystocia in animals [7]. This study was carried out to obtain osteometric measurements of the pelvis of Scottish Fold cats using X-ray images and reveal the biometric differences of these measurement values in terms of sexual dimorphism.

2. Materials and methods

2.1. Experimental animals

The radiographic pelvic images of Scottish Fold cats (n: 36), males (n: 12) and females with dystocia (n: 12) and eutocia (n: 12) at first-time parturition and between the ages of 2–4 years old that were brought to private veterinary clinics in the Bursa province of Türkiye between 2019–2022—were used. Healthy cats that did not have any anatomical disorders and no neoplastic, infectious, congenital, or traumatic skeletal system anomalies were included in the study. The radiographs of the male cats were obtained by bringing them to the clinic for routine veterinary check-ups (Figure 1a). Cats that gave birth

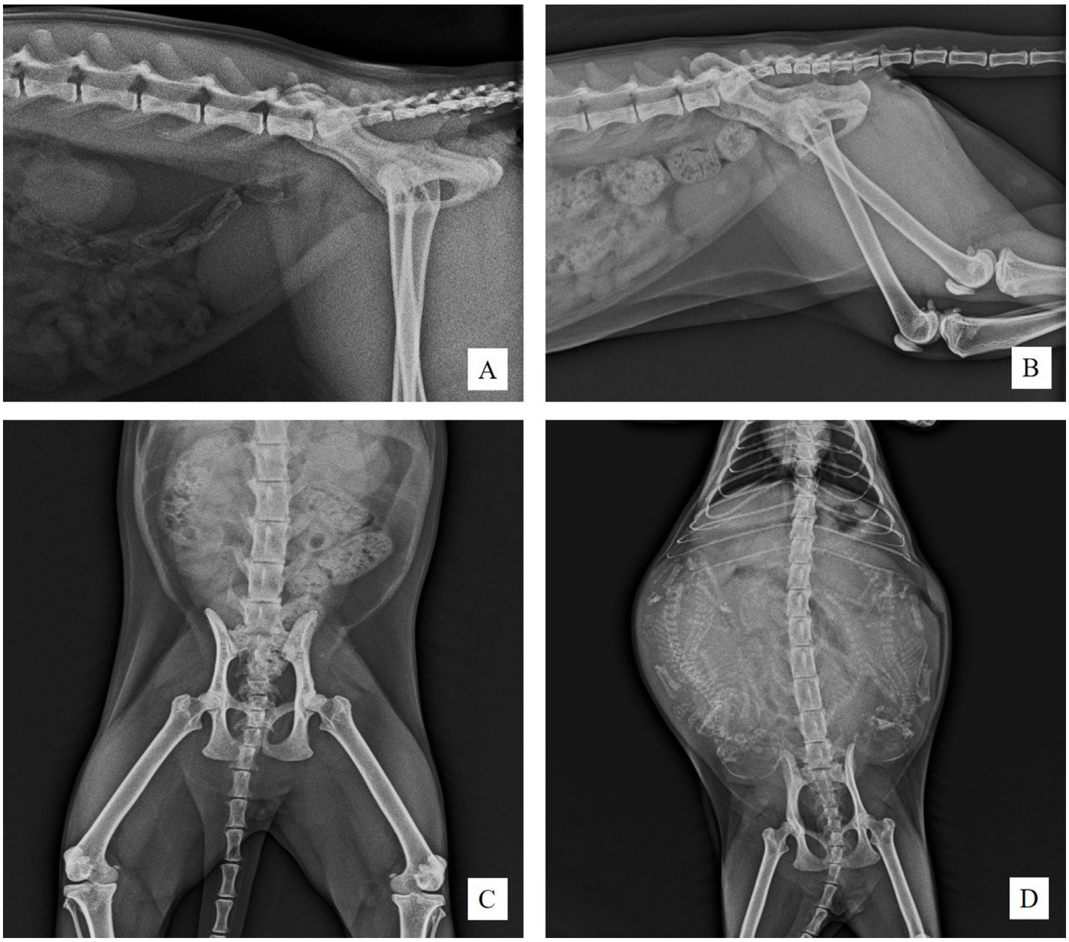

Figure 1. Laterolateral and ventrodorsal projection of the pelvis in Scottish Fold cats. A) Laterolateral radiographic image of a male Scottish Fold cat pelvis; B) Laterolateral radiographic image of a female Scottish Fold cat pelvis; C) Ventrodorsal radiographic image of a Scottish Fold cat pelvis with eutocia; D) Ventrodorsal radiographic image of a Scottish Fold cat pelvis with dystocia.

normally were brought to the clinic for control purposes. Cats found to have completed their parturition with no kittens in the uterus upon radiographic examination constituted the eutocia group (Figures 1b and 1c). A dystocia group was formed using cats brought to the clinic due to an inability to give birth after 6–8 h; these cats had previously passed and underwent operative intervention (Figure 1d). The images obtained in the study were evaluated retrospectively as a result of routine clinical examination procedures. Data use was approved by the Beta Veterinary Office (approval number BETA/RI-2). Necessary ethical permission was obtained from the local ethics committee of Van Yüzüncü Yıl University (23/02/2023, decision no: 2023/04-06).

2.2. Radiological imaging

A Hasvet 838R (838 R, Hasvet, Turkey) X-ray device was used for the X-ray examinations of the cats. The animals were placed in laterolateral and ventrodorsal positions on a disposable cover on an X-ray table. During the procedure, the X-ray machine's parameters were determined as follows: the film-focus distance was 20 cm, the stationary system was 100 cm, and the exposure time was performed at 50–90 KVp/30 mA/0.1–6.3 s.

Laterolateral and ventrodorsal images were obtained from the pelvis of Scottish Fold cats with dystocia and eutocia and male specimens. All image analyses were performed using open-source software (Horos v3.3.6, https://horosproject.org/MacPro Quad Core, Apple Inc., Cupertino, CA, USA). Image measurements were effectuated with electronic calipers in the software program. To evaluate the reproducibility of the values, each measurement value of the cats' pelvis was measured 3 times by the same anatomist, and the average of these measurements was considered.

2.3. Obtaining osteometric measurements

The Nomina Anatomica Veterinaria [17] was used to name the anatomical reference points in the measurements. The measurement points taken were based on data used in previous studies [6, 7,16,18–20]. Linear measurements taken from the laterolateral X-ray images of the pelvis of the Scottish Fold cats were pelvis length (PL), diameter verticalis (VD), conjugata vera (CV), conjugata diagonalis (DC), diameter sagittalis (SGD), diameter sacralis (SD), and total length of the symphysis pelvina (PS). Linear measurements taken from the ventrodorsal X-ray images were coxal tuberosities (CT), diameter transversa (TD), width between acetabulum (AC), greatest width between the lateral tuber ischiadicum (LIT), smallest width between the medial tuber ischiadicum (MIT), foramen obturatum length (FOL), and foramen obturatum width (FOW). In addition, 2 angle measurement values were acquired: the angle between the arcus ischiadicus (IA) and the angle between the VD and the diameter conjugata-inclinatio pelvis (PI). Moreover, pelvic inlet area (PIA) (area of the apertura pelvis cranialis) and pelvic outlet area (POA) (area of the apertura pelvis caudalis) were calculated. PIA and POA were calculated using the simple equations $PIA = (CV/2 + TD/2)^2 \times \pi$ and $POA = (VD/2 + AC/2)^2 \times \pi$, according to previous studies [6,21]. Finally, the height/width measurements between the pelvimetric measurements obtained from the laterolateral and ventrodorsal images were attained. In these measurement values, centimeters (cm) were used for linear measurements, degrees (°) for angle measurements, and square centimeters (cm^2) for area measurements. The measurement points, abbreviations, and definitions of these cat pelvis measurements are presented in Table 1. The reference points used for the osteometric measurements of the pelvis are presented in Figures 2 and 3.

2.4. Statistical analysis

The power of the test was calculated by taking at least 80% to calculate the sample size, and the type-1 error was determined as 5%. Shapiro–Wilk ($n < 50$) and Skewness–Kurtosis tests were used to determine whether the continuous measurements were normally distributed, and parametric tests were applied because the measurements were normally distributed. For descriptive statistics of the study's variables, the mean was expressed as standard deviation. An independent t-test and one-way analysis of variance were performed to compare measurements according to the groups. Duncan's test was used to identify different groups following the analysis of variance. Pearson's correlation coefficients were calculated to determine the relationship between measurements. The statistical significance level (a) was defined as 5% in the calculations, and the SPSS (Windows version 26, IBM Corp., Armonk, NY, USA) statistical package program was used for analysis.

3. Results

Linear pelvimetric measurements were taken from 14 parameters of the ventrodorsal and laterolateral radiological images of the pelvis in Scottish Fold Cats. Subsequently, 2 angle measurement values were taken: pelvic inclination and ischiatic arch. In addition to these measurements, 2 area values were calculated: pelvic inlet and pelvic outlet areas. In other words, 18 parameter measurement values belonging to the pelvis of Scottish Fold cats were obtained. In addition, 36 parameter ratio measurements were collected using the ratios of the length and width measurements of the cats' pelvises. These pelvic measurements were statistically evaluated in terms of sexual dimorphism and are presented in Tables 2–5. Statistically significant differences ($p < 0.05$) were recorded between these measurement values.

Table 1. Pelvis measurement points and related abbreviations in Scottish Fold cats.

Parameter	Abbreviation	Definition
Linear distances (cm)		
1	PL	Pelvis length: Distance between the most distant tuber coxae and tuber ischiadicum
2	VD	Vertical diameter (diameter verticalis): The vertical distance between the cranial end of the pelvic symphysis and the ventral surface of the mid sacrum (pelvis height)
3	CV	Conjugate vera: Distance between the promontorium and cranial end of the symphysis pelvina
4	DC	Diagonal conjugata (conjugata diagonalis): Distance between the promontorium and caudal end of the symphysis pelvina.
5	SGD	Sagittal diameter (diameter sagittalis): Distance between caudal the end of the sacrum and the caudal end of the symphysis pelvina
6	DS	Sacral diameter (diameter sacralis): vertical distance between the caudoventral border of the sacrum and the medial portion of the midcranial symphysis pelvina.
7	PS	Total length of the symphysis pelvina
8	CT	Coxal tuberosities: Horizontal distance greatest width between the tuber coxae
9	TD	Transversal diameter (diameter transversa): Horizontal distance between the interior surfaces of both ilial shafts.
10	AC	Acetabulum: Horizontal distance between the interior surfaces of both acetabuli (pelvis width)
11	LIT	Lateral ischial tuberosities: Horizontal distance greatest width between the tuber ischiadicum
12	MIT	Medial ischial tuberosities: Horizontal distance smallest width between the tuber ischiadicum
13	FOL	Foramen obturatum length: Greatest length of the obturator foramen
14	FOW	Foramen obturatum width: Greatest width of the obturator foramen
Angle measurements (°)		
15	PI	Pelvic inclination (inclinatio pelvis): Angle between the diameter verticalis and the diameter conjugata.
16	IA	Ischiatic arch (arcus ischiadicus): Angle between the ischiatic arch.
Areas (cm^2)		
17	PIA	Pelvic inlet area (area of the cranial pelvic aperture): Planar surface corresponding to the boundary between the pelvic and the abdominal cavity. $PIA = (CV/2 + TD/2)^2 \times \pi$
18	POA	Pelvic outlet area (area of the caudal pelvic aperture): Lower circumference of the lesser pelvis. $POA = (VD/2 + AC/2)^2 \times \pi$

Table 1. (Continued).

Ratios (height/width) measurements (total: 36 parameters)							
PL/CT	VD/CT	CV/CT	DC/CT	SGD/CT	DS/CT	PS/CT	FOL/FOW
PL/TD	VD/TD	CV/TD	DC/TD	SGD/TD	DS/TD	PS/TD	
PL/AC	VD/AC	CV/AC	DC/AC	SGD/AC	DS/AC	PS/AC	
PL/LIT	VD/LIT	CV/LIT	DC/LIT	SGD/LIT	DS/LIT	PS/LIT	
PL/MIT	VD/MIT	CV/MIT	DC/MIT	SGD/MIT	DS/MIT	PS/MIT	

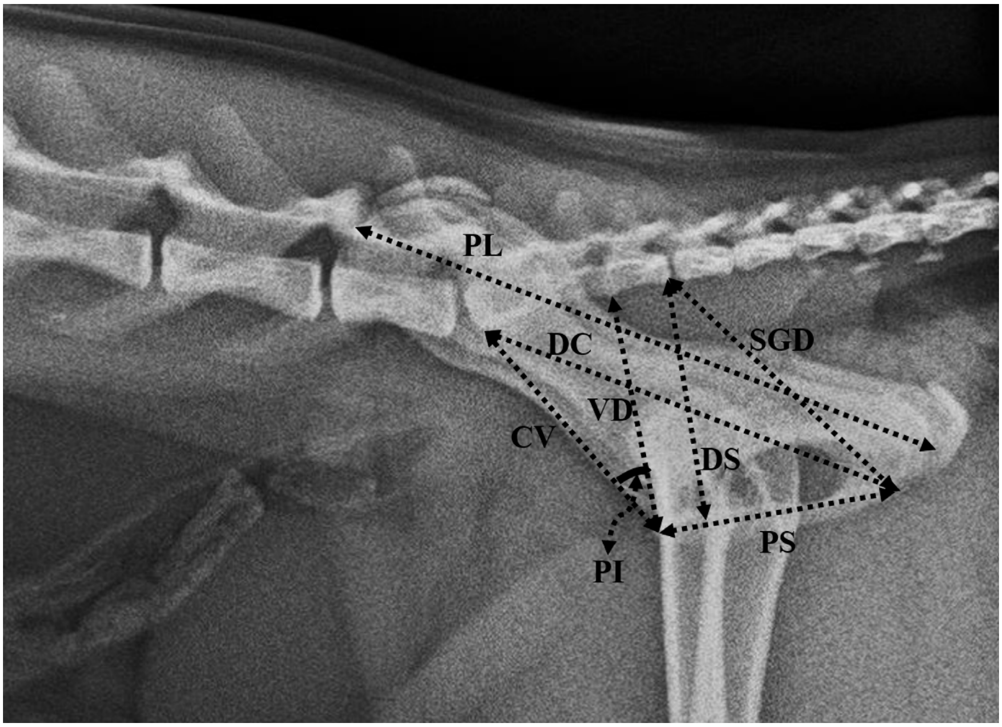

Figure 2. Laterolateral radiography of a female Scottish Fold cat pelvis. Measurements: Pelvis length (PL), conjugate vera (CV), conjugata diagonalis (DC), diameter verticalis (VD), diameter sagittalis (SGD), inclinatio pelvis (PI), diameter sacralis (SD), and total length of the symphysis pelvina (PS).

The descriptive statistics and comparison of the pelvimetric measurement values in Scottish Fold cats are given in Table 2. Observing the table data, PL, VD, DC, SGD, DS, CT, and FOW measurement values do not show a significant difference between the cats with eutocia and those with dystocia; however, these measurement values were found to be statistically significantly higher in male cats compared to the other 2 groups ($p < 0.05$). In addition, the differences between CV, PS, TD, AC, LIT, FOL, PIA, and POA were statistically significant between cats with eutocia and dystocia and the male group ($p < 0.05$). These measurement values were highest in the male cats and higher in the eutocia cats than in cats with dystocia. However, MIT, PI, and IA values were statistically significantly higher in cats with eutocia than in other groups ($p < 0.05$). When the cats with dystocia and eutocia are compared, CV, PS, TD, AC, LIT, MIT, FOL, PI, IA, PIA, and POA were statistically significantly higher in cats with eutocia than in cats with dystocia ($p < 0.05$).

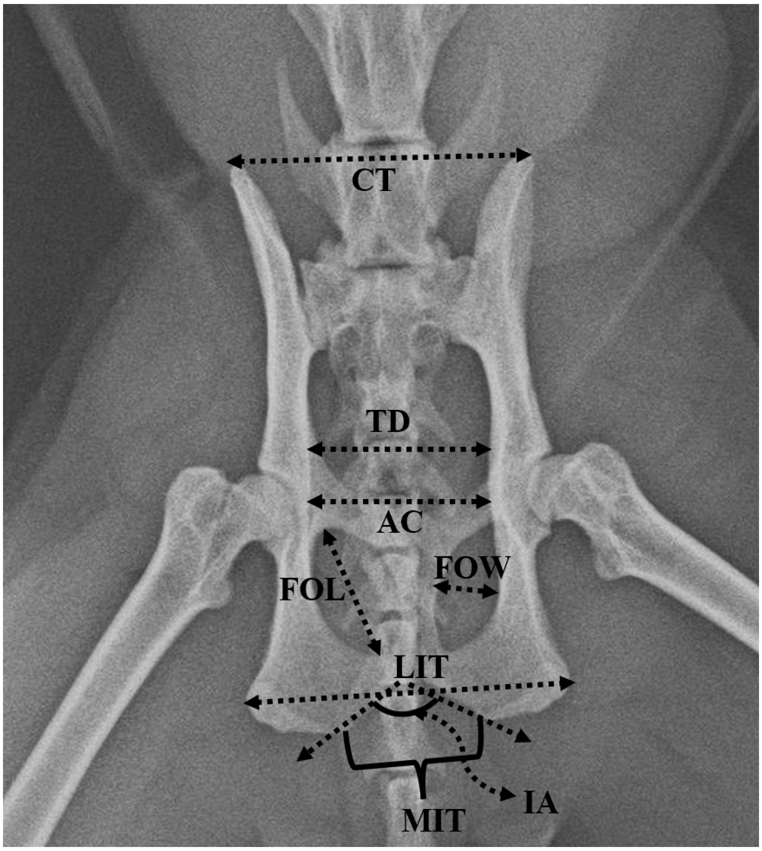

Figure 3. Ventrodorsal radiograph of a female Scottish Fold cat pelvis. Measurements: Coxal tuberosities (CT); diameter transversa (TD); width between acetabulum (AC); greatest width between the lateral tuber ischiadicum (LIT); smallest width between the medial tuber ischiadicum (MIT); foramen obturatum length (FOL); foramen obturatum width (FOW); arcus ischiadicus (IA).

The graph of the morphometric measurement distribution of the pelvis in Scottish Fold cats according to males and females is given in Figure 4. When the graphic data is examined, it can be seen that all values, except for PI and IA, were statistically significantly higher in male than in female cats ($p < 0.05$). However, PI was statistically significantly higher in females than males ($p < 0.05$). Although IA was higher in females than males, this difference was not statistically significant ($p > 0.05$).

The descriptive statistics and comparison of the ratios between the pelvimetric measurement values of the Scottish Fold cats with eutocia and dystocia and males are presented in Table 3. According to the data, statistically significant differences were observed between the 3 groups in the mean ratio measurements, except for VD/AC, CV/AC, PS/TD, and PS/AC mean ratio measurements ($p < 0.05$). In addition, PL/TD, PL/LIT, VD/CT, VD/LIT, VD/MIT, CV/CT, CV/LIT, CV/MIT, DC/TD, DC/AC, DC/MIT, SGD/TD, SGD/LIT, SGD/MIT, DS/MIT, PS/MIT, and FOL/FOW mean ratio measurement values showed statistically significant differences between the groups ($p < 0.05$). Furthermore, while no statistically significant difference was observed between the eutocia and dystocia groups according to DC/CT, SGD/CT, and SGD/AC mean ratio measurements, the average ratio measurement value in male cats was statistically significantly higher than in the other two groups ($p < 0.05$). Similarly, no statistically significant difference was observed between the eutocia and dystocia groups regarding the mean measurement values of PL/AC, DS/CT, and PS/LIT; however, this average ratio was statistically significantly lower in male cats than in the other 2 groups ($p < 0.05$). Finally, according to Table 3's data, mean height/width ratio measurements in the Scottish Fold cats with dystocia were mostly higher (21 parameters out of 36 parameters) than in males and those with eutocia.

Table 4 shows the relationship between pelvic measurement values in male Scottish Fold cats.

Table 2. Descriptive statistics and comparison of pelvimetric measurement values in Scottish Fold cats.

	Male (n: 12)		Eutocia (n: 12)		Dystocia (n: 12)		*p
	Mean	SD	Mean	SD	Mean	SD	
PL	8.032a	0.175	7.807b	0.117	7.659b	0.171	0.001
VD	3.278a	0.108	3.110b	0.060	3.039b	0.100	0.001
CV	3.862a	0.070	3.568b	0.073	3.469c	0.106	0.001
DC	6.650a	0.110	5.585b	0.071	5.563b	0.106	0.001
SGD	4.308a	0.118	3.487b	0.057	3.442b	0.105	0.001
DS	3.134a	0.055	2.829b	0.068	2.851b	0.079	0.001
PS	3.034a	0.080	2.881b	0.087	2.713c	0.055	0.001
CT	4.339a	0.065	3.711b	0.104	3.770b	0.063	0.001
TD	3.114a	0.051	2.883b	0.058	2.693c	0.062	0.001
AC	2.853a	0.050	2.687b	0.061	2.584c	0.063	0.001
LIT	4.778a	0.082	4.195b	0.051	3.952c	0.075	0.001
MIT	1.878b	0.082	1.976a	0.051	0.881c	0.059	0.001
FOL	2.017a	0.079	1.819b	0.059	1.645c	0.060	0.001
FOW	1.243a	0.101	0.820b	0.072	0.876b	0.053	0.001
PI	21.483b	0.787	25.617a	1.449	22.033b	0.521	0.001
IA	110.800b	4.342	118.175a	3.042	106.108c	3.207	0.001
PIA	38.205a	0.857	32.673b	0.952	29.826c	1.409	0.001
POA	29.509a	1.214	26.383b	0.869	24.832c	1.011	0.001

*p < 0.05: Significance levels according to one-way ANOVA test; a,b,c: Difference between the subgroups (Duncan's post-hoc test).

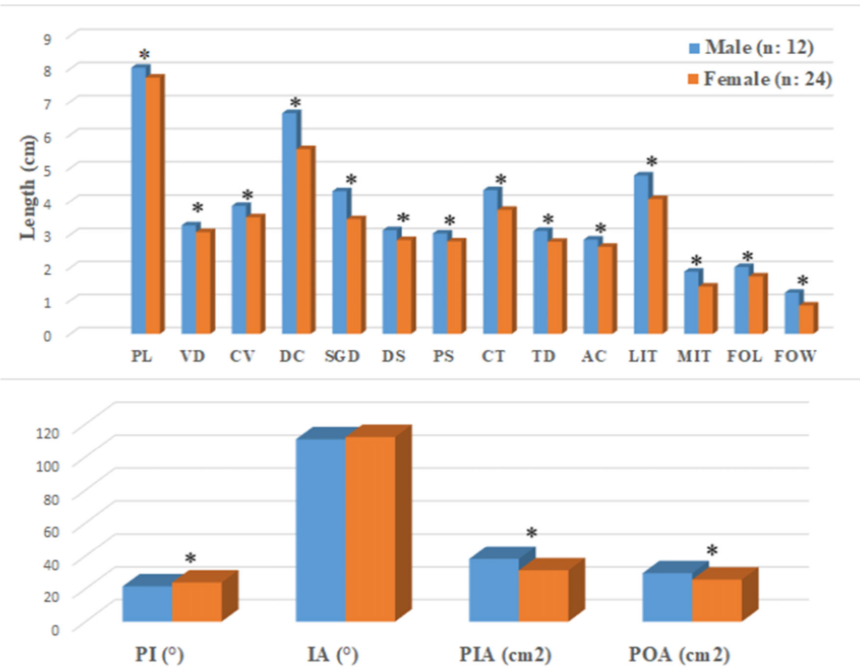

Figure 4. Distribution of pelvimetric measurement values in Scottish Fold cats by sex (*p < 0.05; Independent sample t-test).

Table 3. Descriptive statistics and comparison of the ratios between pelvimetric measurement values of Scottish Fold cats.

	Male (n:12)		Eutocia (n:12)		Dystocia (n:12)		*p
	Mean	SD	Mean	SD	Mean	SD	
PL/CT	1.851c	0.040	2.106a	0.081	2.032c	0.028	0.001
PL/TD	2.580c	0.067	2.709b	0.063	2.845a	0.076	0.001
PL/AC	2.816b	0.071	2.907a	0.074	2.965a	0.096	0.001
PL/LIT	1.681c	0.040	1.861b	0.036	1.939a	0.062	0.001
PL/MIT	4.285b	0.233	3.954b	0.128	8.736a	0.694	0.001
VD/CT	0.755c	0.025	0.839a	0.032	0.806b	0.031	0.001
VD/TD	1.053b	0.036	1.079b	0.024	1.129a	0.047	0.001
VD/AC	1.149a	0.041	1.158a	0.030	1.177a	0.050	0.259
VD/LIT	0.686c	0.029	0.741b	0.016	0.769a	0.027	0.001
VD/MIT	1.747b	0.066	1.575c	0.048	3.464a	0.253	0.001
CV/CT	0.890c	0.024	0.962a	0.029	0.920b	0.033	0.001
CV/TD	1.240b	0.033	1.238b	0.035	1.288a	0.035	0.001
CV/AC	1.354a	0.042	1.329a	0.038	1.343a	0.049	0.361
CV/LIT	0.808c	0.012	0.851b	0.022	0.878a	0.037	0.001
CV/MIT	2.060b	0.110	1.807c	0.066	3.953a	0.274	0.001
DC/CT	1.533a	0.038	1.506b	0.044	1.476b	0.032	0.004
DC/TD	2.136a	0.032	1.938c	0.052	2.067b	0.060	0.001
DC/AC	2.332a	0.060	2.080c	0.063	2.154b	0.062	0.001
DC/LIT	1.392a	0.031	1.332b	0.023	1.408a	0.033	0.001
DC/MIT	3.546b	0.163	2.829c	0.094	6.338a	0.371	0.001
SGD/CT	0.993a	0.031	0.940b	0.031	0.913b	0.036	0.001
SGD/TD	1.384a	0.052	1.210c	0.036	1.279b	0.053	0.001
SGD/AC	1.511a	0.055	1.299b	0.042	1.332b	0.047	0.001
SGD/LIT	0.902a	0.033	0.831c	0.020	0.871b	0.028	0.001
SGD/MIT	2.297b	0.102	1.766c	0.064	3.921a	0.257	0.001
DS/CT	0.722b	0.016	0.763a	0.027	0.756a	0.027	0.001
DS/TD	1.007b	0.021	0.982b	0.033	1.059a	0.036	0.001
DS/AC	1.099a	0.027	1.053b	0.032	1.104a	0.039	0.001
DS/LIT	0.656b	0.020	0.674b	0.018	0.722a	0.027	0.001
DS/MIT	1.671b	0.062	1.432c	0.037	3.251a	0.258	0.001
PS/CT	0.699b	0.018	0.777a	0.040	0.720b	0.019	0.001
PS/TD	0.975a	0.034	1.000a	0.041	1.008a	0.038	0.092
PS/AC	1.064a	0.035	1.073a	0.036	1.050a	0.026	0.253
PS/LIT	0.635b	0.022	0.687a	0.024	0.687a	0.015	0.001
PS/MIT	1.619b	0.094	1.459c	0.069	3.092a	0.199	0.001
FOL/FOW	1.635c	0.162	2.237a	0.244	1.886b	0.151	0.001

*$p < 0.05$: Significance levels according to one-way ANOVA test; a,b,c: Shows the difference between subgroups (Duncan post-hoc test).

Table 4. Correlation between pelvic measurement values in male Scottish Fold cats.

		PL	VD	CV	DC	SGD	DS	PS	CT	TD	AC	LIT	MIT	FOL	FOW	PI	IA	PIA
VD	r	–0.217	1															
CV	r	–0.241	–0.546	1														
DC	r	0.179	–0.055	0.185	1													
SGD	r	–0.175	0.638*	–0.282	–0.290	1												
DS	r	–0.470	0.688*	–0.487	–0.045	0.275	1											
PS	r	0.400	0.188	–0.122	–0.099	0.444	–0.124	1										
CT	r	0.343	0.229	–0.303	–0.231	0.042	0.032	0.330	1									
TD	r	0.072	0.203	–0.185	0.583*	–0.389	0.272	–0.290	0.128	1								
AC	r	0.205	0.134	–0.563	–0.131	–0.226	0.029	–0.039	0.355	–0.008	1							
LIT	r	0.271	–0.398	0.650*	0.152	–0.335	–0.570	–0.200	–0.072	–0.139	–0.036	1						
MIT	r	–0.344	0.518	–0.462	–0.004	0.252	0.497	–0.425	0.114	0.339	0.052	–0.580*	1					
FOL	r	0.220	–0.624*	0.232	0.045	–0.642*	–0.576*	–0.554	–0.095	0.048	0.201	0.465	–0.019	1				
FOW	r	0.452	0.323	0.297	0.196	0.189	0.021	0.001	0.097	–0.020	0.054	0.112	0.292	–0.041	1			
PI	r	0.278	0.301	–0.033	0.191	0.480	–0.013	0.286	–0.215	–0.023	–0.326	–0.051	0.125	–0.015	0.301	1		
IA	r	–0.409	0.471	–0.585*	–0.060	0.237	0.396	–0.389	–0.013	0.200	0.281	–0.617*	0.914**	–0.013	0.195	–0.007	1	
PIA	r	0.262	–0.356	0.770**	0.543	–0.504	–0.257	–0.296	–0.185	0.486	–0.507	0.487	–0.191	0.239	0.251	–0.045	–0.391	1
POA	r	–0.103	0.916**	–0.697*	–0.100	0.454	0.606*	0.143	0.344	0.176	0.520	–0.356	.469	–0.453	0.301	0.127	0.519	–0.508

* Correlation is significant at the $p < 0.05$; ** Correlation is significant at the $p < 0.01$; r: Pearson Correlation Coefficient

Accordingly, significant positive correlations were observed between VD and SGD, DS, and POA, at 63.8%, 68.8%, and 91.6%, respectively ($p < 0.05$). However, there was a statistically significant negative correlation of 62.4% between VD and FOL ($p < 0.05$). While there was a positive correlation of 65.0% and 77.0% between CV and LIT and PIA, negative significant correlations were found between CV and IA and POA, at 58.5% and 69.7% ($p < 0.05$). There was a statistically significant correlation of 58.3% between DC and TD ($p < 0.05$), and a significant negative correlation of 64.2% existed between SGD and FOL ($p < 0.05$). While there was a positive and significant correlation of 60.6% between DS and POA, a negative significant correlation was observed at a rate of 57.6% with FOL ($p < 0.05$). There was a statistically significant negative correlation between LIT and MIT and IA, at a rate of 58.0% and 61.7% ($p < 0.05$), and a strong positive correlation of 91.4% between MIT and IA ($p < 0.05$).

The correlation between the pelvimetric measurement values in the Scottish Fold cats with eutocia and dystocia is given in Table 5. Accordingly, a negative significant correlation was observed between FOW and IA with PL in the cats with eutocia at rates of 70.2% and 60.5%, respectively ($p < 0.05$). Similarly, a statistically negative correlation between FOL and IA was found at a rate of 69.3% ($p < 0.05$). When the specified measurement values are examined, there were significant positive correlations between VD and POA, CV and PIA, CT and FOW, TD and PIA, and AC and POA at rates of 78.8%, 79.0%, 61.6%, 62.4%, and 79.6%, respectively ($p < 0.05$).

In the cats with dystocia, there were statistically positive correlations between PL and CT, VD and POA, CV and DS, CV and PIA, DC and MIT, TD and FOL, TD and PIA, LIT and IA, and FOL and PIA at rates of 79.6%, 83.4%, 64.1%, 93.0%, 63.2%, 74.8%, 77.6%, 58.0%, and 70.7%, respectively ($p < 0.05$). However, a statistically significant negative correlation was determined at a rate of 70.7% between DS and DC ($p < 0.05$).

4. Discussion

Osteometric measurements of the pelvis in animals provide crucial data for research in various scientific fields, especially in forensic, evolutionary, and developmental sciences [20,22]. In addition, pelvimetric data obtained from the pelvis can be used in researching different species within larger animal species, determining the morphological variations within species, determining special reproductive management programs in a specific animal, preventing problems related to animal selection for reproductive management programs, and controlling the healthy parturition and early diagnosis of congenital pelvis changes [8,13,19]. In recent years, various medical imaging methods such as the X-ray and computed tomography have been widely used in imaging the pelvis and related complex anatomical structures, obtaining pelvic measurement values from these images, and evaluating pathological conditions in the region, especially in small domestic animals like cats [6,7,19,20]. In the present study, measurement values such as osteometric, surface area, ratio, and angles were determined using the laterolateral and ventrodorsal radiographic images of the pelvis of adult Scottish Fold cats, and these pelvimetric values were evaluated in terms of sexual dimorphism.

In studies examining the osteometric features of cat pelvises in terms of sexual dimorphism, the measurement parameters of the pelvis were mostly higher in male cats; however, it has been reported that the angle measurement values of the pelvis are generally higher in female cats [6,7,19,20,22]. In a study conducted to determine the radiographic pelvimeters of cats with dystocia, Celimli et al. [6] reported that pelvimetric and area measurement values in cats between the ages of 2–3 were higher in males than in females except in the diameter transversa, but the difference between the values between male and female cats was not statistically significant. In addition, in the same study, the authors reported that in the pelvis measurements of cats with eutocia and dystocia, other osteometric and area measurement values, besides the "width between tuber coxae" measurement value, were statistically significantly higher in cats with eutocia than in cats with dystocia. In this study, when the differences between males and females were examined, it was seen that all of the remaining 16 measurement values, except for PI and IA, were statistically significantly higher in male than in female cats. From this data, we can conclude that the pelvis of Scottish Fold cats is larger in males than in females. In addition, these pelvic measurements were higher in cats with eutocia (excluding DS) than in cats with dystocia.

When general studies on this topic were examined, the angle measurements in the pelvis were generally higher in females than males [19,22–25]. In the current study, the mean PI and IA in male cats was 21.48 ± 0.79° and 110.80 ± 4.34°, respectively; in cats with eutocia, the mean value for PI and IA was 25.62 ± 1.45° and 118.18 ± 3.04°, respectively; in cats with dystocia, the mean value was 22.03 ± 0.52° and 106.11 ± 3.21°, respectively. Accordingly, we can interpret that the pelvis angles are generally wider in females than males. Similarly, it was determined that the pelvis angles were wider in cats with eutocia than in cats with dystocia. This allows for a comfortable parturition in cats with eutocia.

In a study performed by Ferraz et al. [18] to determine the pelvimetric features in the Agouti (*Dasyprocta prymnolopha*) breed under human care, mean PIA and POA values in males and females were calculated as 77.83

Table 5. Correlation between pelvic measurement values in Scottish Fold cats with eutocia and dystocia.

↓ / →		PL	VD	CV	DC	SGD	DS	PS	CT	TD	AC	LIT	MIT	FOL	FOW	PI	IA	PIA	POA
PL	r		−0.085	−0.133	0.252	−0.446	−0.318	0.194	0.796**	0.335	0.078	−0.160	−0.353	0.086	0.216	0.575	−0.220	0.044	−0.027
VD	r	0.415		0.104	−0.271	0.481	0.440	0.015	−0.109	−0.111	−0.075	0.168	0.006	−0.029	0.018	0.425	0.223	0.028	0.834**
CV	r	0.240	−0.129		−0.068	0.082	0.641*	−0.013	−0.087	0.490	0.127	−0.415	0.215	0.545	0.043	−0.218	-0.398	0.930**	0.155
DC	r	−0.222	−0.384	−0.465		0.000	−0.707*	0.500	0.277	0.084	0.132	0.237	0.632*	0.068	0.317	0.106	0.033	−0.015	−0.165
SGD	r	0.198	0.327	0.296	0.127		0.204	0.198	−0.358	−0.188	0.178	0.228	0.291	−0.314	0.202	0.129	0.339	−0.017	0.521
DS	r	−0.403	0.225	−0.369	−0.056	−0.169		−0.151	−0.286	0.089	0.061	−0.260	−0.277	0.193	−0.208	−0.074	−0.167	0.503	0.417
PS	r	0.542	0.450	−0.371	0.162	0.211	0.063		−0.003	−0.455	0.404	0.367	0.339	−0.333	−0.010	0.320	−0.320	−0.202	0.238
CT	r	−0.549	−0.303	0.275	0.118	−0.044	0.076	−0.515		0.464	0.096	−0.153	−0.455	0.416	0.096	0.569	0.094	0.130	−0.038
TD	r	0.136	0.343	0.014	−0.300	−0.322	−0.118	−0.332	−0.125		−0.303	−0.575	−0.116	0.748**	0.274	0.090	−0.086	0.776**	−0.266
AC	r	0.160	0.252	0.145	−0.421	−0.371	0.160	0.221	−0.001	0.199		0.556	0.203	−0.256	0.019	−0.271	0.269	−0.034	0.488
LIT	r	0.002	0.039	−0.192	0.054	−0.424	0.017	−0.172	−0.030	0.485	0.286		0.420	−0.480	0.228	−0.176	0.580*	−0.541	0.454
MIT	r	−0.154	0.120	−0.197	−0.346	−0.402	0.472	−0.390	−0.281	0.443	−0.178	0.196		−0.089	0.307	−0.434	0.061	0.108	0.112
FOL	r	0.456	0.051	0.012	0.012	0.190	−0.192	0.054	−0.488	0.046	−0.513	0.307	0.317		−0.244	0.038	−0.156	0.707*	−0.171
FOW	r	−0.702*	−0.470	0.040	0.183	−0.187	0.226	−0.427	0.616*	−0.252	0.319	0.190	−0.243	−0.569		0.038	0.244	0.149	0.026
PI	r	0.030	−0.131	0.248	−0.233	−0.161	−0.479	−0.091	0.043	0.342	0.002	−0.103	−0.172	−0.105	−0.270		−0.123	−0.122	0.227
IA	r	−0.605*	−0.104	0.089	−0.390	−0.440	0.223	−0.423	0.360	0.241	0.323	−0.157	0.236	−0.693*	0.353	0.403		−0.322	0.345
PIA	r	0.269	0.113	0.790**	−0.550	0.034	−0.355	−0.495	0.141	.0624*	0.237	0.149	0.121	0.037	−0.121	0.398	0.217		0.001
POA	r	0.363	0.787**	0.016	−0.511	−0.033	0.241	0.419	−0.191	0.346	0.796**	0.207	−0.035	−0.294	−0.093	−0.079	0.144	0.228	

* Correlation is significant at $p < 0.05$; ** Correlation is significant at $p < 0.01$; r: Pearson's correlation coefficient.
↓ : Pelvimetric measurements of Scottish Fold cats with eutocia.
→ : Pelvimetric measurements of Scottish Fold cats with dystocia.

± 2.06 cm^2, 20.07 ± 0.57 cm^2, 82.38 ± 3.91 cm^2, and 24.76 ± 1.37 cm^2, respectively. In another study conducted by Morend et al. [16] on the osteometric measurements of the pelvis in lynxes, mean PIA and POA in males and females was 75.60 ± 12.14 cm^2, 71.72 ± 11.59 cm^2, 72.23 ± 14.13 cm^2, and 67.59 ± 13.32 cm^2, respectively. Campos et al. [8] determined that these measurements were 57.09 ± 8.22 cm^2 and 51.86 ± 9.46 cm^2 in the French Bulldog. Monteiro et al. [7] calculated that these values were 33.58 ± 5.82 cm^2, 28.24 ± 3.92 cm^2, 35.96 ± 2.37 cm^2, and 30.92 ± 2.72 cm^2 in Mesaticephalic male and female cats and 29.15 ± 2.68 cm^2, 26.21 ± 2.73 cm^2, 29.27 ± 3.98 cm^2, and 25.51 ± 2.93 cm^2 in Brachycephalic male and female cats, respectively. Celimli et al. [6] reported that the same values were 35.19 ± 0.86 cm^2, 29.93 ± 1.10 cm^2, 32.98 ± 1.00 cm^2, and 26.71 ± 0.90 cm^2 in male and female cats aged 2–3 years and 28.48 ± 1.15 cm^2 and 22.66 ± 1.01 cm^2 in cats with dystocia, respectively. In the present study, these measurement values were calculated as 38.21 ± 0.86 cm^2 and 29.21 ± 1.21 cm^2 in males, 32.67 ± 0.95 cm^2 and 26.38 ± 0.87 cm^2 in cats with eutocia, and 29.83 ± 1.41 cm^2 and 24.83 ± 1.01 cm^2 in cats with dystocia, respectively. Looking at the data, we can conclude that these areas are larger in males than females within the same species and larger in females with eutocia than in those with dystocia. There are differences between the sexes and differences in terms of animal species in the pelvis.

Monteiro et al. [7] reported that the height/width ratio measurements of the pelvis were higher in mesaticephalic cats than in brachycephalic cats among males. In that study, it was determined that the VD/AC ratio was higher in female mesaticephalic cats, and the SGD/TD and SGD/AC ratio measurement values were higher in female brachycephalic cats. However, no significant difference was observed between these height/width ratio measurements between males and females in the present study. Moreover, height/width ratio measurements in cats with dystocia with no pelvic skeletal deformities, such as pelvis fractures, stenosis, or traumatic pelvis disorders, were higher than in females with no radiological skeletal anomalies, and this ratio was statistically not significant among all measurement values [6]. In the present study, mean height/width ratio measurements in the Scottish Fold cats with dystocia were mostly higher (21 parameters out of 36) than in males and those with eutocia. This finding can mean that if these height/width ratios are high, the probability of dystocia in cats will also be increased.

In a study by Compas et al. [8], in which 20 French Bulldog bitches between the ages of 2–4 were assessed, positive correlations (except pelvimetric ratios) were determined in all dogs between the external and internal radiographic pelvic parameters of the pelvis. Leão et al. [14], assessing *Tamandua tetradactyla*, and Pinheiro et al. [13], who evaluated the common marmoset, determined the animals' radiographic pelvimetry and reported that while there were negative correlations between osteometric measurement values of the pelvis, positive correlations mainly occurred. In another study by Yilmaz and Demircioğlu [20], which determined the morphometric characteristics of the pelvis in 16 Van cats (8 males and 8 females), while there were mostly positive statistically significant relationships between the osteometric measurement values of the pelvis in the male cats, statistically significant correlations were found in both positive and negative directions in the female specimens. In the current study, there were mostly strong positive and statistically significant correlations and statistically significant negative correlations in the pelvic measurements of the Scottish Fold cats. These results show that the variables are related to one another. The correlations determined from the pelvis may be useful in determining sexual dimorphism between the sexes, external body measurements, the body condition score in these cats, and various clinical functions, especially reproduction.

The study has some limitations. Measurements were obtained from X-ray images, primarily because this kind of imaging is affordable. Advanced medical imaging methods, such as computed tomography, magnetic resonance imaging, or measurements taken by making 3D models of images, are available, but these methods could not be used because of the high costs of the devices and the need for specialist personnel. Another limitation concerns the sample population as we could only access images of cats aged 2–4 years. The study could have benefitted from comparing more animals of different ages. Finally, we think it would be interesting for similar studies to determine whether there is any change in pelvic dimensions in multiparous cats, an aspect not investigated in this study.

Statistically, the differences in the biometric values of Scottish Fold cat pelvises in males and females with eutocia and dystocia were determined using X-ray images. The study results can be used as a guide in the evaluation of X-ray images of Scottish Fold cats with various pelvis-related pathological disorders, as well as in sex determination, the determination of taxonomic classification among cat species, and animal selection for reproductive management programs. The study findings can also aid veterinarians in various clinical applications and be used in zooarchaeology.

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