DOI: 10.1002/vms3.1572

WILEY

ORIGINAL ARTICLE

RUMINANTS

Developmental three-dimensional examination of the pelvic cavity of Hamdani crossbred sheep fetuses (*Ovis aries*) in the last two periods of gestation

Fatma İşbilir | **Barış Can Güzel**

Faculty of Veterinary Medicine, Department of Anatomy, Siirt University, Siirt, Türkiye

Correspondence
Fatma İşbilir, Faculty of Veterinary Medicine, Department of Anatomy, Siirt University, Siirt 56100, Türkiye.
Email: fatmaisbilir42@gmail.com

Abstract

Background: Türkiye is a country in the world ranking in terms of sheep breeding. Hamdani crossbred sheep breed is one of the sheep breeds that can adapt to the difficult conditions in our country. In addition, the sentence may be corrected as 'Especially in the southeastern part of the Türkiye, crossbreeding is preferred by breeders to increase the yield characteristics of sheep'.

Objectives: In our study, it was aimed to perform a pelvimetric analysis of Hamdani crossbred sheep fetuses in the second and third trimesters by three-dimensional modelling method.

Methods: For this purpose, a total of 40 second-trimester (10 females, 10 males) and third-trimester (10 females, 10 males) fetuses were used. The pelvises of the fetuses were imaged with CT and 3D models were created. Sixteen pelvimetric measurements were performed from the models. The results obtained were evaluated statistically.

Results: The study found statistically significant differences between male and female fetuses in terms of vertical diameter (VD) and *foramen obturatum* width (FOW) measurement parameters in the second trimester. In the third trimester, there were statistically significant differences between genders in acetabulum (AC) ($p < 0.01$), medial ischial tuberosities (MIT), and ischiatic arch (IA) ($p < 0.05$) parameters. As a result of the correlation analysis, it was determined that the pelvis length (PL) measurement parameter was positively correlated with different parameters in varying degrees in both periods, while the IA parameter did not show significant correlations with the other parameter in the last two periods of pregnancy.

Conclusion: In conclusion, the data obtained will be useful in pelvimetric evaluations of human and animal fetuses, anatomy education, zooarchaeology and taxonomy studies.

KEYWORDS
computed tomography, fetal pelvis, Hamdani crossbreed sheep, pelvimetry, three-dimensional modelling

1 | INTRODUCTION

Ossa coxae is the bone structure responsible for the attachment of the hindlimb to the trunk. The section formed by the ossa coxae laterally and ventrally, the sacral vertebrae dorsally and the first caudal vertebrae are called the pelvis. The cavity of the pelvis is known as the *cavum pelvis* and the canal is known as the *canalis pelvis*. The cavity contains the organs of the digestive, urinary and genital systems, as well as the birth canal. In adult animals, gender can be determined using morphometric features of bones in the skeletal system (Dayan et al., 2023; Duro et al., 2021; Gündemir et al., 2020a; Güzel & İşbilir, 2024; Jashari et al., 2022; Steyn & Patriquin, 2009; Şenol et al., 2022). Depending on the effects of sex hormones on the pelvis, the pelvic skeleton is differentiated between sex. Therefore, it can be used for sex determination in adult mammals and birds (Charles, 2013; Dawson et al., 2011; Gündemir et al., 2020b; Komar & Buikstra, 2008; Manuta et al., 2023; Yılmaz et al., 2024). Especially when pelvic and skull bones are used together, sex determinations can reach a very strong prediction level of 98% (Garvin, 2012; Şahiner & Yalçıner, 2007). Apart from sex determination, the shape and dimensions of the pelvic structure are important factors in the labour process (Sporri et al., 1994). This necessitates a good knowledge of the anatomical structure of the *canalis pelvis*. Pelvimetry has been used to assess the size of the pelvic canal and compare it with the size of the fetus in various species. Radiography (X-ray) is the most common method used for this purpose (Eneroth et al., 1999; Monteiro et al., 2013). Computed tomography, magnetic resonance imaging and ultrasonography are also used (Ohlerth & Scharf, 2007; Stark et al., 1985). To overcome the disadvantages of two-dimensional (2D) conventional imaging methods, models and measurements of anatomical structures are made with three-dimensional (3D) modelling from CT slices in the medical sector (Allowen et al., 2016; Aydoğdu et al., 2021; İşbilir & Guzel, 2023; Lloyd et al., 2018; Mirjana et al., 2014; Morone et al., 2019; Parthasarathy, 2014). Pelvic development and diameters may vary depending on many factors such as race, body size, gender, nutrition, movement rate, hormones, environment and climatic conditions (Karakaş, 1988).

Sheep stand out with their role in organic production in meeting sustainability demands (Koyuncu & Taşkın, 2016). Hamdani sheep breed is a preferred breed in terms of milk and fleece yield and has a fat tail structure (Al-Barzinji et al., 2011). Especially, crosses of Hamdani sheep are raised in the south-eastern of the Türkiye for its production traits and preferred by breeders for well adaptation ability to the region (Turgut et al., 2023; Turgut et al., 2024; Turgut & Koca, 2024).

Investigation of bone development during gestation periods is necessary to understand the changes that occur during these periods. Studies on bones in the fetal period in sheep are limited. In our study, measurements of the fetal pelvic structure of Hamdani crossbred ewes in the second and third trimesters of pregnancy using a 3D modelling technique and comparisons between sexes in the same trimester were made. The data obtained will contribute to various branches of science such as gynaecology, zooarchaeology and taxonomy.

2 | MATERIALS AND METHODS

2.1 | Animals

In our study on pelvis measurements of second and third trimesters of sheep pregnancy, a total of 40 fetuses from the second trimester (10 females and 10 males) and the third trimester (10 females and 10 males) were used. Fetuses were collected from the uteruses of pregnant animals slaughtered in the slaughterhouse of Siirt province. Fetuses from uteruses with a single pregnancy were included in the study. The gestation period was determined using the formula X = 2.1(Y+17) (X = gestation period in days, Y = crown-anus length) (Noakes et al., 2001; Singh et al., 2023). $X = 2.1\,(Y + 17)$ ($X = Y =$ CRL). Two separate groups were formed in the second trimester (68–99 days) and third trimester (110–140 days).

2.2 | Radiological imaging

Computerised tomography scans of the collected fetuses were performed at the Private Siirt Hayat Hospital. The pelvises of second- and third-trimester fetuses were scanned at 200 MA 639 mGY and 0.625 mm slice thickness with a 64-detector multislice Siemens brand computed tomography device at 80 kV. The images obtained were saved in DICOM format. Images were transferred to 3D-Slicer 5.6.2 software and 3D reconstruction images were created.

2.3 | Osteometric measurements

The Nomina Anatomica Veterinaria (Nomina Anatomica Veterinaria, 2017) was used to name the anatomical reference points in the measurements. The measurement parameters were determined based on the studies of Yilmaz et al. (2023) and Demircioglu et al. (2021). Measurements were made on the resulting 3D models (Figures 1 and 2). Linear measurements taken from the laterolateral 3D model of the pelvis:

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*

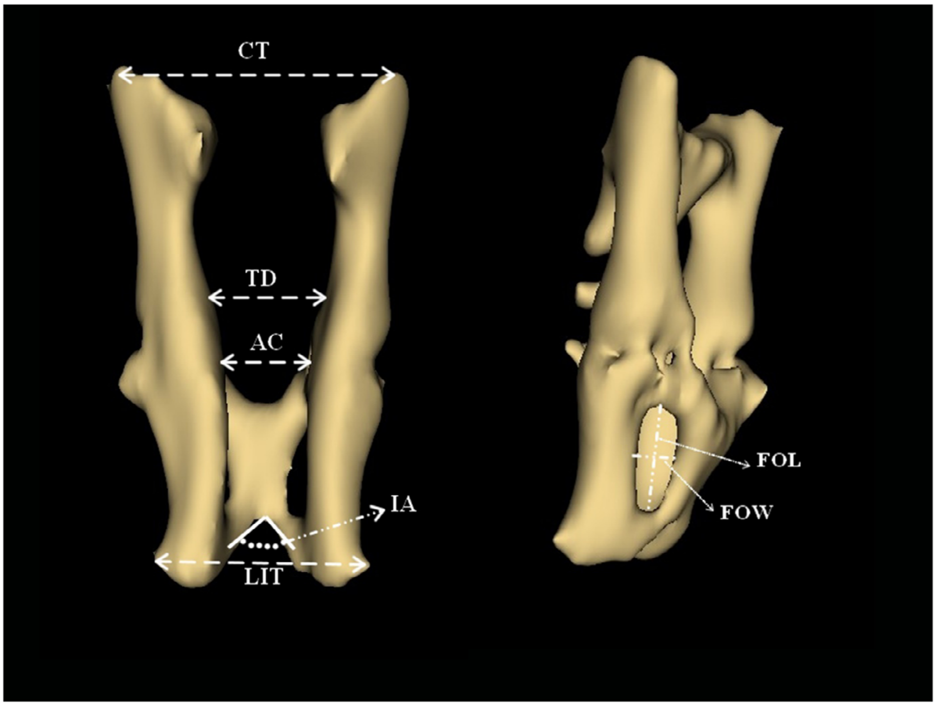

FIGURE 1 Morphometric measurement points of the pelvis in Hamdani crossbred sheep fetuses (dorsal and lateral). AC, acetabulum; CT, coxal tuberosities; FOL, *foramen obturatum* length; FOW, *foramen obturatum* width; IA, ischiatic arch; LIT, lateral ischial tuberosities; TD, transversal diameter.

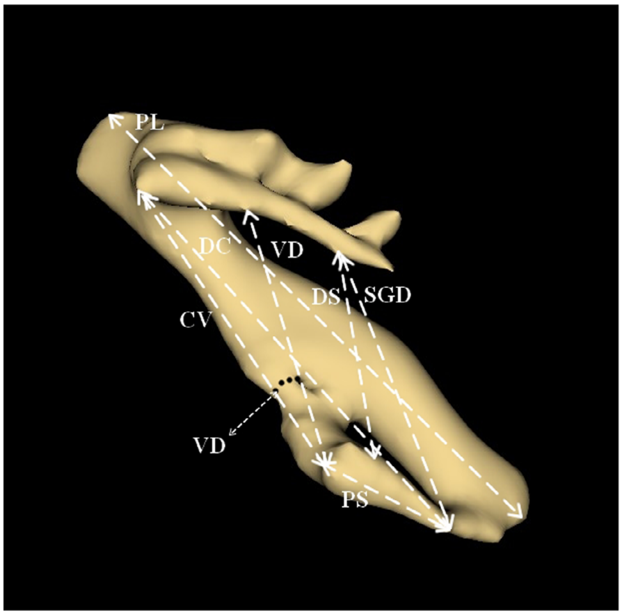

FIGURE 2 Morphometric measurement points of the pelvis in Hamdani crossbred sheep fetuses (lateral). CV, conjugate vera; DC, diagonal conjugata; DS, sacral diameter; PL, pelvis length; PS, total length of the *symphysis pelvina*; SGD, sagittal diameter; VD, vertical diameter.

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
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.

2.4 | Statistical analysis

Shapiro–Wilk ($n < 50$) and Skewness-Kurtosis tests were used to determine whether continuous measurements were normally distributed. Descriptive statistics of the study variables were expressed as mean and standard deviation. Independent *t*-test was used to compare measurements by groups (male and female fetal pelvis within the same trimester). Pearson's correlation coefficients were calculated to determine the relationship between measurements. Statistical analyses were performed using SPSS 22.0 software. Statistical significance level was set up $p < 0.05$.

TABLE 1 Measurements of the pelvis of second trimester sheep.

	Gender	*N*	Min.	Mean	Max.	Std. error of mean	*p*
PL	Male	10	35.02	45.6200	51.18	1.4	NS
	Female	10	37.45	39.6700	42.02	0.44	
VD	Male	10	16.20	17.9070	19.56	0.34	**
	Female	10	15.03	15.9740	16.59	0.14	
CV	Male	10	25.18	26.4240	26.42	0.31	NS
	Female	10	23.01	24.2730	26.18	0.31	
DC	Male	10	23.05	25.2510	28.45	0.46	NS
	Female	10	19.05	20.6110	23.01	0.32	
SGD	Male	10	35.12	36.4340	38.65	0.35	NS
	Female	10	32.18	33.6250	34.56	0.22	
DS	Male	10	30.12	31.0040	32.15	0.25	NS
	Female	10	25.26	27.5760	28.48	0.32	
PS	Male	10	12.25	13.0870	13.65	0.15	NS
	Female	10	10.99	11.4459	12.36	0.13	
CT	Male	10	16.35	17.2280	18.48	0.19	NS
	Female	10	13.84	14.4100	15.20	0.13	
TD	Male	10	8.84	9.2440	9.98	0.11	NS
	Female	10	7.14	8.2920	9.02	0.19	
AC	Male	10	7.45	7.8300	8.45	0.10	NS
	Female	10	6.02	7.1000	7.85	0.16	
LIT	Male	10	9.48	10.0550	10.67	0.13	NS
	Female	10	8.15	8.6770	9.41	0.14	
MIT	Male	10	6.02	6.3700	6.84	0.09	NS
	Female	10	5.02	5.3560	6.01	0.09	
FOL	Male	10	7.18	7.4640	8.02	0.08	NS
	Female	10	6.02	6.2750	6.58	0.06	
FOW	Male	10	3.12	3.7380	4.02	0.08	**
	Female	10	2.99	3.0600	3.20	0.02	
PI	Male	10	13.25	13.9320	14.56	0.11	NS
	Female	10	12.01	12.4850	13.02	0.12	
IA	Male	10	26.41	27.7870	28.47	0.25	NS
	Female	10	25.02	26.7110	36.02	1.05	

**$p < 0.01$.

3 | RESULTS

Sixteen pelvimetric measurements were taken from the pelvis of second- and third-trimester sheep fetuses. The measurements' descriptive statistics and *p* values are presented in Tables 1 and 2, and correlation results are presented in Tables 3 and 4. The PL measurement parameter revealed that males were larger than females in the second and third trimesters. VD and FOW parameters were found to be statistically significant in the pelvis of second-trimester sheep. When the third-trimester measurement parameters were examined, it was determined that the AC measurement parameter was larger in females than males and was statistically highly significant. MIT and IA parameters were found to be larger in females than males and were statistically significant. According to the data we obtained, it was determined that females were larger than males in some measurements in the third trimester compared to the second trimester. When the third-trimester correlation analysis was examined, it was seen that the PL measurement parameter had a strong positive correlation with the VD, CV, DC, SGD, DS, PS, CT, and TD measurement parameters. Additionally, it was determined that the IA parameter had no correlation with any measurement parameters. When the correlation analysis of the second trimester was examined, it was seen that the PL

TABLE 2 Measurements of the pelvis of third-trimester sheep.

	Gender	*N*	Min.	Mean	Max.	Std. error of mean	*p*
PL	Male	10	72.25	75.0050	78.14	0.51	NS
	Female	10	66.14	68.4990	68.49	0.33	
VD	Male	10	31.01	32.7000	35.62	0.46	NS
	Female	10	26.95	28.1270	29.74	0.28	
CV	Male	10	54.78	56.6660	59.67	0.43	NS
	Female	10	50.25	51.6560	53.21	0.30	
DC	Male	10	35.02	36.8350	38.41	0.33	NS
	Female	10	30.28	32.1970	34.56	0.38	
SGD	Male	10	51.84	53.8570	55.20	0.38	NS
	Female	10	46.28	47.7160	49.02	0.26	
DS	Male	10	42.05	42.8240	44.12	0.20	NS
	Female	10	35.14	37.5160	38.47	0.35	
PS	Male	10	18.41	19.6420	21.02	0.24	NS
	Female	10	15.45	16.2410	17.09	0.16	
CT	Male	10	37.41	38.6980	40.10	0.28	NS
	Female	10	31.05	33.4530	35.15	0.37	
TD	Male	10	16.25	17.3800	18.25	0.21	NS
	Female	10	18.47	20.1420	22.03	0.35	
AC	Male	10	13.00	13.5720	14.20	0.11	**
	Female	10	14.01	14.5510	15.55	0.20	
LIT	Male	10	23.14	23.5560	23.87	0.07	NS
	Female	10	24.16	24.4130	25.02	0.10	
MIT	Male	10	10.45	10.6260	11.02	0.06	*
	Female	10	10.47	10.8490	11.50	0.12	
FOL	Male	10	13.02	13.4910	13.82	0.07	NS
	Female	10	12.14	12.4260	12.85	0.08	
FOW	Male	10	6.15	6.5234	6.85	0.08	NS
	Female	10	7.01	7.5350	8.02	0.10	
PI	Male	10	26.54	27.5030	28.54	0.23	NS
	Female	10	25.02	26.0330	27.50	0.23	
IA	Male	10	54.01	56.2720	59.02	0.50	*
	Female	10	56.12	57.4440	58.14	0.19	

*$p < 0.05$.
**$p < 0.01$.

measurement parameter had a normal positive correlation with DC, DS and CT. In addition, there is no correlation analysis with any of the IA measurement parameters as in the third trimester.

4 | DISCUSSION

Morphometric analysis of animal bones is a method frequently used to reveal morphological variations within a species, to investigate different species within animal genera, to determine differences between sexes, and to provide important data for a wide range of scientific fields such as evolutionary, forensic and developmental sciences (Pitakarnnop et al., 2017). Morphometric data obtained from the pelvis are very important for the early diagnosis of congenital pelvis (Campos et al., 2019).

At the level of anatomical science, both internal and external measurements of the pelvis are considered important for reproductive and obstetricians. Reproduction depends on the pelvis and a good pelvis means a good, strong, productive life, and thus good, healthy offspring with high productivity can be produced (Coopman et al.,

TABLE 3 Correlation analysis of measurements of pelvis of second-trimester sheep.

	PL	VD	CV	DC	SGD	DS	PS	CT	TD	AC	LIT	MIT	FOL	FOW	PI	IA
PL	1															
VD	0.45	1														
CV	0.418	0.677(*)	1													
DC	0.725(*)	0.728(*)	0.565	1												
SGD	0.424	0.746(*)	0.712(*)	0.706(*)	1											
DS	0.786(*)	0.656(*)	0.567	0.824(**)	0.776(*)	1										
PS	0.598	0.723(*)	0.677(*)	0.880(**)	0.771(*)	0.782(*)	1									
CT	0.755(*)	0.704(*)	0.643(*)	0.869(**)	0.745(*)	0.898(**)	0.860(**)	1								
TD	0.461	0.529	0.704(*)	0.659(*)	0.533	0.522	0.656(*)	0.558	1							
AC	0.489	0.487	0.633(*)	0.549	0.332	0.578	0.558	0.579	0.600(*)	1						
LIT	0.579	0.724(*)	0.557	0.863(**)	0.719(*)	0.769(*)	0.818(**)	0.813(**)	0.51	0.609(*)	1					
MIT	0.745(*)	0.746(*)	0.679(*)	0.892(**)	0.745(*)	0.762(*)	0.815(**)	0.808(**)	0.600(*)	0.475	0.759(*)	1				
FOL	0.639(*)	0.747(*)	0.791(*)	0.840(**)	0.796(*)	0.824(**)	0.865(**)	0.897(**)	0.728(*)	0.598	0.772(*)	0.836(**)	1			
FOW	0.523	0.773(*)	0.753(*)	0.761(*)	0.731(*)	0.725(*)	0.675(*)	0.798(*)	0.535	0.645(*)	0.677(*)	0.791(*)	0.813(**)	1		
PI	0.683(*)	0.672(*)	0.607(*)	0.749(*)	0.718(*)	0.827(**)	0.799(*)	0.874(**)	0.594	0.533	0.632(*)	0.745(*)	0.874(**)	0.760(*)	1	
IA	0.129	0.187	0.18	0.26	0.251	0.308	0.179	0.236	0.155	0.379	0.461	0.072	0.106	0.135	0.016	1

*$p < 0.05$.
**$p < 0.01$.

TABLE 4 Correlation analysis of measurements of pelvis of third-trimester sheep.

	PL	VD	CV	DC	SGD	DS	PS	CT	TD	AC	LIT	MIT	FOL	FOW	PI	IA
PL	1															
VD	0.898(**)	1														
CV	0.952(**)	0.904(**)	1													
DC	0.807(**)	0.765(*)	0.784(*)	1												
SGD	0.884(**)	0.876(**)	0.908(**)	0.887(**)	1											
DS	0.887(**)	0.838(**)	0.908(**)	0.876(**)	0.935(**)	1										
PS	0.893(**)	0.780(*)	0.851(**)	0.830(**)	0.837(**)	0.914(**)	1									
CT	0.876(**)	0.924(**)	0.851(**)	0.849(**)	0.919(**)	0.872(**)	0.843(**)	1								
TD	0.811(**)	0.861(**)	0.773(*)	0.831(**)	0.823(**)	−0.866(**)	0.783(*)	0.854(**)	1							
AC	0.704(*)	0.637(*)	0.657(*)	0.565	0.571	0.587	0.753(*)	0.638(*)	0.463	1						
LIT	0.796(*)	0.726(*)	0.752(*)	0.772(*)	0.793(*)	0.747(*)	0.801(**)	0.735(*)	0.668(*)	0.727(*)	1					
MIT	−0.375	−0.394	−0.263	−0.183	−0.297	−0.225	−0.353	−0.314	0.253	.622(*)	0.581	1				
FOL	0.788(*)	0.823(**)	0.781(*)	0.815(**)	0.815(**)	0.839(**)	0.848(**)	0.875(**)	0.722(*)	0.642(*)	0.742(*)	−0.275	1			
FOW	0.765(*)	0.832(**)	0.757(*)	0.805(**)	0.815(**)	−0.844(**)	0.788(*)	0.876(**)	0.878(**)	0.518	0.555	0.145	0.782(*)	1		
PI	0.641(*)	0.630(*)	0.637(*)	0.520	0.734(*)	0.631(*)	0.667(*)	0.694(*)	0.452	0.464	0.683(*)	0.515	0.697(*)	0.465	1	
IA	−0.259	−0.178	−0.263	0.483	−0.422	−0.422	0.444	−0.357	0.28	0.196	0.197	−0.196	−0.412	0.491	−0.236	1

*$p < 0.05$
**$p < 0.01$.

2003). Furthermore, the assessment of animal safety through specific reproductive management programs is carried out in case of a healthy parturition (Campos et al., 2019). With anatomical knowledge of the bone pelvis structures, we can obtain the average pelvic diameters required for reproduction (Coopman et al., 2003). Studies have observed that the pelvic bone is effective in egg retention in birds (Koca et al., 2023b) and difficult births in mammals (Koca et al., 2023a).

Bahadır and Yıldız (2016) stated that the closer the vertical diameter is to the caudal of the sacrum, the easier the birth will be. In a study conducted on 8- to 12-month-old goats, vertical diameter was reported as 8.1 cm on average (Seif et al., 2018). In 12-week-old sexually mature Awassi sheep, the vertical diameter varied between 8.36 ± 0.04 and 10.61 ± 0.03 cm and in domestic black goats between 7.55 ± 0.03 and 10.55 ± 0.10 cm (Alhanosh & Hasso, 2022). In another study conducted on gazelles, it was determined that the vertical diameter was closer to the caudal part of the sacrum in female animals than in male animals (Demircioğlu & Gezer İnce, 2020). In dog breeds, it was mentioned that the vertical diameter fell further behind the sacrum in dogs with large body structures (Akçasız et al., 2024). In our study, similar to the results expressed in gazelles, a statistical difference was observed between the sexes in terms of vertical diameter in animals in the second trimester. In the third trimester, there was no such difference.

As a result of radiographic examination in British shorthair cats with dystocia and eutocia, the AC measurement parameter was reported as 2.05 ± 0.10 mm in cats with dystocia and 2.30 ± 0.12 mm in cats with eutocia (Koca et al., 2023a,b). The same parameter was determined as 13.57 ± 0.37 mm in male fetuses and 14.55 ± 0.64 mm in female fetuses in the third trimester, and a statistical difference was observed between the sexes ($p < 0.01$).

In our study, the MIT parameter was determined as 6.37 ± 0.09 mm in males and 5.35 ± 0.09 mm in females in second-trimester fetuses, while it was determined as 10.62 ± 0.06 mm in males and 10.84 ± 0.12 mm in females in third-trimester fetuses. In gazelles, the same parameter was reported as 46.18 ± 5.29 mm in females and 37.96 ± 0.68 mm in males. In addition, a statistically significant difference was expressed between the sexes (Demircioğlu & Gezer İnce, 2020). According to our study results, in terms of the MIT parameter, no difference was observed between the sexes in the second trimester, while the difference between the sexes in the third trimester was statistically significant ($p < 0.05$).

It is known that high ischial arch and pelvic inclination in females have an important place among the factors facilitating labour (Bahadır & Yıldız, 2016; Dursun, 2006; Pitakarnnop et al., 2017). In studies conducted on Van cat (Yılmaz et al., 2020), New Zealand rabbits (Özkadif et al., 2014), Kangal dogs (Atalar et al., 2017), and gazelles (Demircioglu et al., 2021), it was determined that this angle was higher in females than males. In a study conducted on British shorthair cats, this angle had a statistically greater value in eutocia cats than in dystocia cats (Koca et al., 2023a,b). In a study, the similarities between the pelvic structures of sheep and humans were mentioned (Urbankova et al., 2017). In a survey conducted in the human fetal period, in terms of ischiatic arch angle (subpubic angle), significant sexual dimorphism was noticed in 14- to 22-week-old fetuses, but the values were always less than 90° in both sexes and in female infants, they were towards the upper side as in adults (Mahboobul Haque et al., 2016). In our study results, the ischial arch angle did not differ between male and female animals in second term fetuses, but in third term fetuses, this angle had a greater value in females than in male ewes. This result may indicate that the ischiatic arch angulation is fully formed close to birth.

As a result of the correlation analysis, it was determined that pelvis length had a positive relationship with certain parameters at different rates in both gestation periods. This indicates that pelvic length and other parameters grow with the growing offspring. This result confirms the interpretation that weight and age are important in most pelvic measurements (Celimli et al., 2008; Dobak et al., 2018; Eneroth et al., 1999; Nahkur et al., 2011). In our study, the angulation of the ischiatic arch did not show any correlation with any parameter in both fetuses.

5 | CONCLUSION

Consequently, this study is the first attempt to examine the pelvic structure of sheep fetuses (*Ovis aries*) in three dimensions using the CT technique and to perform pelvimetric analyses. It is thought that the results of the study will be useful in the evaluation of CT images of fetuses in animals and humans, anatomy education, gynaecological diseases, and zooarchaeological studies.

AUTHOR CONTRIBUTIONS

Fatma Işbilir: Project administration; conceptualisation; investigation; original draft; writing—review and editing. **Barış Can Güzel**: Methodology; validation; software; data curation.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

FUNDING INFORMATION

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

With the ethics committee report numbered 2024/05/29, the Siirt University Experimental Animals Application and Research Center approved the procedures used in our investigation.

ORCID

Fatma İşbilir https://orcid.org/0000-0002-6110-1302

Barış Can Güzel https://orcid.org/0000-0002-2504-120X

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1002/vms3.1572.

REFERENCES

Akçasız, Z. N., Demircioğlu, İ., Özkan, E., Manuta, N., & Guzel, B. C. (2024). Three-dimensional pelvimetric evaluation of the pelvic cavity in different dog breeds. *Turkish Journal of Veterinary Research*, *8*(1), 13–18. https://doi.org/10.47748/tjvr.1356441

Al-Barzinji, Y. M., Lababidi, S., Rischkowsky, B. A., Al-rawi, A. A., Tibbo, M., Hassen, H., & Baum, M. (2011). Assessing genetic diversity of Hamdani sheep breed in Kurdistan region of Iraq using microsatellite markers. *African Journal of Biotechnology*, *10*, 15109–15116.

Alhanosh, A. A., & Hasso, A. A. (2022). Radiographic and ultrasonic study of pelvic bones in awassi ewes and local she goat and relationship with age of sexual maturity. *Iraqi Journal of Veterinary Sciences*, *36*(3), 627–631.

Allowen, E., Thibaud, S., Ardern, H.-B., Carly, A., Richard, A., Pietro, V., Greger, L., Thomas, C., & Keith, D. (2016). The use of close range photogrammetry in zooarchaeology: Creating accurate 3D models of wolf crania to study dog domestication. *Journal of Archaeolgical Science:Reports*, *9*, 87–93. https://doi.org/10.1016/j.jasrep.2016.06.028

Atalar, O., Koç, M., Yüksel, M., & Arkaş Alklay, A. (2017). Three-dimensional evaluation of pelvic cavity in Kangal dogs by computerized tomography. *FÜ Sağlık Bilimleri Veteriner Dergisi*, *31*, 105–109.

Aydoğdu, S., Eken, E., & Koçak, M. (2021). Sexual dimorphism in the sheep corpus callosum using 3 tesla MRI. *Eurasian Journal of Veterinary Sciences*, *37*(4), 225–234.

Bahadir, A., & Yildiz, H. (2016). *Veteriner Anatomi Hareket Sistemi ve İç organlar* (pp. 1–90). Ezgi Bookselling.

Campos, A. I. M., Uchoa, D. C., Monteiro, C. L. B., da Silva, T. F. P., & da Silva, L. D. M. (2019). Establishing a body and pelvic biometric standard and determining their relationship in the French Bulldog. *Journal of Advanced Veterinary Research*, *2*, 105.

Celimli, N., Seyrek Intas, D., Yilmazbas, G., Seyrek Intas, K., Keskin, A., Kumru, I. H., & Kramer, M. (2008). Radiographic pelvimetry and evaluation of radiographic findings of the pelvis in cats with dystocia. *Tierärztliche Praxis*, *36*, 277–284.

Charles, B. E. (2013). *A geometric morphometric analysis of the human ossa coxae for sex determination* (PhD Thesis). University of Wisconsin-Milwaukee.

Coopman, F., De Smet, S., Gengler, N., Haegeman, A., Jacobs, K., Van Poucke, M., Laevens, H., van Zeveren, A., & Groen, A. F. (2003). Estimating internal pelvic sizes using external body measurements in the double-muscled Belgian Blue beef breed. *Animal Science*, *76*(2), 229–235.

Dawson, C., Ross, D., & Mallett, X. (2011). *Sex determination, Forensic Anthropology, 2000 to 2010*. CRC Press.

Dayan, M. O., Demircioğlu, İ., Koçyiğit, A., Güzel, B. C., & Karaavci, F. A. (2023). Morphometric analysis of the skull of Hamdani sheep via three-dimensional modelling. *Anat Histol Embryol*, *52*(2), 215–222.

Demircioglu, I., Yilmaz, B., Gündemir, O., & Dayan, M. O. (2021). A three-dimensional pelvimetric assessment on pelvic cavity of gazelle (*Gazella subgutturosa*) by computed tomography. *Anatomia Histologia Embryologia*, *50*(1), 43–49.

Demircioğlu, I., & Gezer Ince, N. (2020). Three-dimensional modeling of computed tomography images of limb bones in gazelles (*Gazella subgutturosa*). *Anatomia Histologia Embryologia*, *49*(6), 695–707. https://doi.org/10.1111/ahe.12564

Dobak, T. P., Voorhout, G., Vernooij, J. C. M., & Boroffka, S. A. E. B. (2018). Computed tomographic pelvimetry in English bulldogs. *Theriogenology*, *118*, 144–149. https://doi.org/10.1016/j.theriogenology.2018.05.025

Duro, S., Gündemir, O., Sönmez, B., Jashari, T., Szara, T., Pazvant, G., & Kambo, A. (2021). A different perspective on sex dimorphism in the adult hermann's tortoise: geometric morphometry. *Zoological studies*, *60*, e9. https://doi.org/10.6620/ZS.2021.60-09

Dursun, N. (2006). *Veteriner Anatomi I*. Medisan Yayınevi, 10.Baskı.

Eneroth, A., Linde-Forsberg, C., Uhlhorn, M., & Hall, M. (1999). Radiographic pelvimetry for assessment of dystocia in bitches: A clinical study in two terrier breeds. *Journal of Small Animal Practice*, *40*, 257–264. https://doi.org/10.1111/j.1748-5827.1999.tb03076.x

Garvin, H. M. (2012). Adult sex determination: Methods and application. In: D. Dirkmaat (Ed.), *A companion to forensic anthropology* (pp. 239–247). Wiley-Blackwell.

Gündemir, O., Özkan, E., Dayan, M. O., & Aydoğdu, S. (2020a). Sexual analysis in Turkey (Meleagris gallopavo) neurocranium using geometricmorphometric methods. *Turkish Journal of Veterinary & Animal Sciences*, *44*(3), 681–687.

Gündemir, O., Özkan, E., İnce, N. G., Demircioğlu, I., Aydoğdu, S., Koçyiğit, A., & Dayan, O. (2020b). Investigation of os coxae in horses using geometric morphometry method. *Harran Üniversitesi Veteriner Fakültesi Dergisi*, *9*(2), 170–176.

Güzel, B. C., & İşbilir, F. (2024). Morphometric analysis of the skulls of a ram and ewe Romanov sheep (*Ovis aries*) with 3D modelling. *Veterinary Medicine and Science*, *10*(2), e1396. https://doi.org/10.1002/vms3.1396

Haque, M., Faruqi, N. A., & Yunus, S. M. (2016). Morphometric study of subpubic angle in human fetuses. *Journal of Clinical and Diagnostic Research: JCDR*, *10*(1), AC01–AC04. https://doi.org/10.7860/JCDR/2016/17699.7051

İşbilir, F., & Güzel, B. C. (2023). Morphometric analysis of the mandible of ram and ewe romanov sheep (*1*) with 3D modelling: A CT study. *Anatomia, Histologia, Embryologia*, *52*(5), 742–751. https://doi.org/10.1111/ahe.12932

Jashari, T., Duro, S., Gündemir, O., Szara, T., Ilieski, V., & Choudhary, O. P. (2022). Morphology, morphometry and some aspects of clinical anatomy in the skull and mandible of Sharri sheep. *Biol*, *77*(2), 423–433.

Karakaş, S. (1988). Pelvis çapları üzerine etki eden faktörler. *Atatürk Üniversitesi Tıp Bülteni*, *20*(2), 313–318.

Koca, D., Yilmaz, O., & Avcilar, T. (2023a). Radiographic measures of the pelvis differ in British shorthair cats with dystocia and eutocia. *Veterinary Radiology & Ultrasound: The Official Journal of the American College of Veterinary Radiology and the International Veterinary Radiology Association*, *64*(5), 798–805. https://doi.org/10.1111/vru.13265

Koca, D., Yılmaz, O., Şahin, M. E., & Avcılar, T. (2023b). Radiographic pelvimetry in budgerigars with and without egg retention. *Kafkas Universitesi Veteriner Fakültesi Dergisi*, *29*(5), 497–504. https://doi.org/10.9775/kvfd.2023.29499

Komar, D. A., & Buikstra, J. E. (2008). *The estimation of sex from skeletal remains (sex diagnosis), Forensic anthropology: Contemporary theory and practice* (pp. 126–136). Oxford University Press.

Koyuncu, M., & TAŞKIN, T. (2016). Ekolojik koyun ve keçi yetiştiriciliği. *Hayvansal Üretim*, *57*(1), 56–62.

Lloyd, A. C., Miguel, Á. M., Julia, A., José, Y., Diego, G., & Manuel, D. (2018). Testing accuracy in 2D and 3D geometric morphometric methods for cut mark identification and classification. *Peer J*, *5*(6), e5133. https://doi.org/10.7717/peerj.5133

Manuta, N., Gündemir, O., & Yalin, E. E. (2023). Pelvis shape analysis with geometric morphometry in crossbreed cats. *Anatomia, Histologia, Embryologia*, *52*(4), 611–618.

Mirjana, D., Concepción, R., Patricia, G., Inmaculada, A., & Miguel, B. (2014). Morphometric sex estimation from 3D computed tomography os coxae model and its validation in skeletal remains. *International Journal of Legal Medicine*, *128*, 879–888. https://doi.org/10.1007/s00414-014-1033-x

Monteiro, C. L. B., Campos, A. I. M., Madeira, V. L. H., Silva, H. V. R., Freire, L. M. P., Pinto, J. N., de Souza, L. P., & da Silva, L. D. M. (2013). Pelvic differences between brachycephalic and mesaticephalic cats and indirect pelvimetry assessment. *Veterinary Record*, *172*(1), 16. https://doi.org/10.1136/vr.100859

Morone, P. J., Shah, K. J., Hendricks, B. K., & Cohen-Gadol, A. A. (2019). Virtual, 3-dimensional temporal bone model and its educational value for neurosurgical trainees. *World Neurosurgery*, *122*, e1412–e1415. https://doi.org/10.1016/j.wneu.2018.11.074

Nahkur, E., Ernits, E., Jalakas, M., & Järv, E. (2011). Morphological characteristics of pelves of estonian holstein and estonian native breed cows from the perspective of calving. *Journal of Veterinary Medicine Series C:*

Anatomia Histologia Embryologia, *40*(5), 379–388. https://doi.org/10.1111/j.1439-0264.2011.01082.x

Noakes, D. E., Parkinson, T. J., & Gary, C. (2001). *Arthur's veterinary reproduction and obstetrics* (pp. 68). 8th Edition. W. B. Saunders.

Nomina Anatomica Veterinaria. (2017). *Prepared by the international committees on veterinary gross anatomical nomenclature and authorized by the general assembly of the world association of veterinary anatomists* (6th ed.). The Editorial Committee.

Ohlerth, S., & Scharf, G. (2007). Computed tomography in small animalsbasic principles and state of the art applications. *The Veterinary Journal*, *173*, 254–271.

Ozkadif, S., Eken, E., & Kalaycı, I. (2014). A three-dimensional reconstructive study of pelvic cavity in the New Zealand rabbit (*Oryctolagus cuniculus*). *TheScientificWorldJournal*, *2014*, 489854.

Parthasarathy, J. (2014). 3D modeling, custom implants and its future perspectives in craniofacial surgery. *Annals of Maxillofacial Surgery*, *4*(1), 9–18. https://doi.org/10.4103/2231-0746.133065

Pitakarnnop, T., Buddhachat, K., Euppayo, T., Kriangwanich, W., & Nganvongpanit, K. (2017). Feline (*Felis catus*) skull and pelvic morphology and morphometry: gender-related difference? *Anatomia, Histologia, Embryologia*, *46*(3), 294–303.

Şahiner, Y., & Yalçıner, H. (2007). Erkek ve bayanlarda kafatası kemiğinden geometrik morfometri metoduyla cinsiyet tayini ve ramus flexura. *Atatürk Üniversitesi Veteriner Bilimleri Dergisi*, *2*, 134–142.

Seif, M. A., Karkoura, A. A., Bakary, R. M. E., Alsafy, M. A., & Abumandour, M. A. (2018). Computed tomography and gross anatomy of the pelvis of the Barki male goat (Capra hircus). *Alexandria Journal for Veterinary Sciences*, *56*(1), 18–24.

Şenol, E., Gündemir, O., Duro, S., Szara, T., Demiraslan, Y., & Karadağ, H. (2022). A pilot study: Can calcaneus radiographic image be used to determine sex and breed in cats? *Veterinary Medicine and Science*, *8*(5), 1855–1861.

Singh, L. K., Singh, U., & Singh, P. (2023). Fetal dystocia and estimation of fetal age in Sheep. *The Indian Journal of Animal Reproduction*, *44*(2), 104–106.

Sporri, S., Gyr, T., Schollerer, A., Werlen, S., & Schneider, H. (1994). Methods, techniques and assessment criteria in obstetric pelvimetry. *Zeitschrift für Geburtshilfe und Perinatologie*, *198*(2), 37–46.

Stark, D. D., McCarthy, S. M., Filly, R. A., Parer, J. T., Hricak, H., & Callen, P. W. (1985). Pelvimetry by magnetic resonance imaging. *AJR*, *144*(5), 947–950.

Steyn, M., & Patriquin, M. L. (2009). Osteometric sex determination from the pelvis – Does population specificity matter? *Forensic Science International*, *191*(1–3), 113.

Turgut, A. O., Gülendağ, E., Koca, D., & Üner, S. (2023). Milk composition traits of hamdani crossbreed sheep raised under extensive management. *ISPEC Journal of Agricultural Sciences*, *7*(2), 271–279.

Turgut, A. O., Gülendağ, E., Koca, D., & Üner, S. (2024). PAEP gene restriction fragment length polymorphism and its effects on milk composition in cross-bred Hamdani sheep. *Journal of Advances in VetBio Science and Techniques*, *9*(1), 35–41.

Turgut, A. O., & Koca, D. (2024). Serum anti-müllerian hormone levels during estrus and diestrus phases of the estrous cycle and its possible effect on fertility in cross-bred Hamdani sheep. *Pakistan Veterinary Journal*, *44*(1), 205–209.

Urbankova, I., Vdoviakova, K., Rynkevic, R., Sindhwani, N., Deprest, D., Feola, A., Herijgers, P., Krofta, L., & Deprest, J. (2017). Comparative anatomy of the ovine and female pelvis. *Gynecologic and Obstetric Investigation*, *82*(6), 582–591. https://doi.org/10.1159/000454771

Yılmaz, O., Koca, D., & Avcılar, T. (2023). Radiographic pelvimetry in Scottish Fold cats: Sex-related differences. *Turkish Journal of Veterinary & Animal Sciences*, *47*(5), 433–445.

Yılmaz, O., Koca, D., Sahin, M. E., & Avcilar, T. (2024). Sex determination in budgerigars using radiographic pelvimetry. *Veterinary Medicine and Science*, *10*(1), e1340.

Yilmaz, O., Soyguder, Z., Yavuz, A., & Dundar, I. (2020). Three-dimensional computed tomographic examination of pelvic cavity in Van Cats and its morphometric investigation. *Anatomia, Histologia, Embryologia*, *49*(1), 60–66. https://doi.org/10.1111/ahe.12484

How to cite this article: İşbilir, F., & Güzel, B. C. (2024). Developmental three-dimensional examination of the pelvic cavity of Hamdani crossbred sheep fetuses (*Ovis aries*) in the last two periods of gestation. *Veterinary Medicine and Science*, *10*, e1572. https://doi.org/10.1002/vms3.1572