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Pelvis Anatomy and Morphometric Analysis in New Zealand Rabbits

Yeni Zelanda Tavşanlarında Pelvis Anatomisi ve Morfometrik Analizi

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ABSTRACT

This study aims to obtain three-dimensional models of the cavum pelvis in New Zealand rabbits of both genders using CT images, to measure the pelvis diameters and angles through the created digital models, and to compare female and male New Zealand Rabbits in terms of sexual dimorphism. A total of 20 New Zealand rabbits, 10 females and 10 males, were used in this study. Computed tomography (CT) images of the animals were taken, the images were reconstructed with the MIMICS 20.1 program, and a three-dimensional model of the pelvic cavity was obtained from the two-dimensional images. Morphometric data were obtained by making diameter and angle measurements on the resulting 3D model. Then, the rabbits were dissected and the os coxae was exposed and the anatomical formations were named. When pelvimetry measurements in female and male rabbits were compared, it was seen that all values except pelvic tilt were higher in females. The data reveal that there is no significant difference in the volume and surface area of the right and left os coxae between male and female rabbits ($P > .05$). In this study comparing the morphometric differences of the pelvis in female and male New Zealand rabbits, volume and surface area data were shared for the first time. The collected data could be used for sex discrimination in rabbits, assist physicians in diagnosing patients, serve as a reference for clinical practices, and form the basis for new research.

Keywords: 3D modelling, computed tomography, New Zealand rabbit, pelvic cavity, pelvic bones

ÖZ

Bu çalışmanın amacı, Yeni Zelanda tavşanlarının BT görüntüleri kullanarak her iki cinsiyetteki cavum pelvis'in üç boyutlu modellerini elde etmek, oluşturulan dijital modeller üzerinde pelvis çaplarını ve açı ölçümlerini gerçekleştirerek, dişi ve erkek Yeni Zelanda tavşanlarını cinsel dimorfizm açısından karşılaştırmaktır. Çalışmada 10'u dişi, 10'u erkek olmak üzere toplam 20 adet Yeni Zelanda tavşanı kullanıldı. Hayvanların bilgisayarlı tomografi (BT) görüntüleri alındıktan sonra, görüntüler MIMICS 20.1 programı ile yeniden yapılandırarak, iki boyutlu görüntülerden pelvik boşluğun üç boyutlu modeli elde edildi. Ortaya çıkan 3 boyutlu model üzerinde çap ve açı ölçümleri yapılarak morfometrik veriler elde edildi. Daha sonra tavşanlar diseke edilerek os coxae ortaya çıkarıldı ve anatomik oluşumlar isimlendirildi. Dişi ve erkek tavşanlarda pelvimetrik ölçümler karşılaştırıldığında dişilerde pelvik eğim dışındaki tüm değerlerin daha yüksek olduğu görüldü. Veriler, erkek ve dişi tavşanlar arasında sağ ve sol os coxae'nin hacmi ve yüzey alanı açısından anlamlı bir fark olmadığını ortaya koymaktadır ($p>0.05$). Dişi ve erkek Yeni Zelanda tavşanlarında pelvisin morfometrik farklılıklarının karşılaştırıldığı bu çalışmada hacim ve yüzey alanı verileri ilk kez paylaşıldı. Toplanan verilerin, tavşanlarda cinsiyet ayrımında kullanılabileceği, hekimlere hastalıkların teşhisinde yardımcı olacağı, klinik uygulamalara referans teşkil edeceği ve yeni araştırmalara temel oluşturacağı düşünülmektedir.

Anahtar Kelimeler: 3D modelleme, bilgisayarlı tomografi, Yeni Zelanda tavşanı, pelvik boşluk, pelvik kemikler

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INTRODUCTION

The pelvis is the lower part of the trunk located between the abdomen and the hind limbs. The pelvis is formed by the articulation of the two os coxae at the ventral midline with the pubic symphysis and the os sacrum dorsomedially through the iliosacral joints. This frame connects the axial skeleton to the femurs and transfers the weight of the body to the hind limb.[1,2]

Animal dissections teach the structure of organs, function, and lay the foundation for advanced skills in sample preparation, comparative research, and veterinary practice. However, access to animal tissues limits the learning and study of anatomy through dissection, considering costs and ethical considerations.[3,4] In addition, the use of two-dimensional pictures in learning complex regions and the difficulty in imagining the three-dimensional structure make anatomy education difficult.[4,5] In recent years, three-dimensional models have begun to be preferred in anatomy education because they are practical to use and have a long duration of use. The development of three-dimensional scanning technology and the examination of tissues together with cross-sectional imaging methods increase the importance of three-dimensional anatomical models.[6,7] Computed tomography, one of the methods used in 3D modeling, is an imaging method that uses X-rays to create detailed pictures or scans of structures inside the body. CT scans images of bones, soft tissues, organs, and vessels within the body from different angles and allows them to be viewed in sections.[8] A 3D model of the desired structure is created from these images. In this way, the structures of organs can be observed, measurements can be made, animal research models can be developed, and it helps the physician in the diagnosis of bone diseases and surgical operations.[7,9]

The rabbit is a preferred experimental animal due to its high fertility, short generation period, and low cost. It is also used in the recognition of diseases in humans and animals as an excellent experimental clinico-anatomical example.[10,11] The pelvic cavity in rabbits, as in many mammals, plays a crucial role in supporting reproductive and digestive functions. The pelvic cavity in rabbits is formed by a set of fused bones, including os ilium, os ischii, and os pubis.[2,12] These bones articulate to create a sturdy pelvic girdle, providing support for the organs within. The pelvic bones' arrangement varies among species, influencing the overall shape and size of the pelvic cavity.[13,14] Rabbits are known for their prolific reproductive capabilities, making the understanding of their pelvic anatomy crucial.[10] Although there are many scientific studies that contribute to our understanding of the 3D anatomy of the pelvic cavity in humans and animals, no literature has been found except for a few studies[5,10] studying the anatomy of the pelvic cavity in rabbits. This study aims to obtain three-dimensional models of the cavum pelvis in New Zealand Rabbits of both genders using CT images, to measure the pelvis diameter and angles through the created digital models, and to compare female and male New Zealand rabbits in terms of sexual dimorphism.

MATERIALS AND METHODS

Materials

In the study, 20 healthy (10 females, 10 males) New Zealand rabbits (14 month old and weight of 2200-3500 g) cadavers were used. This study was approved by the Ethics Committee of Selcuk University Faculty of Veterinary Medicine Experimental Animal Production and Research Center (Date: 02.11.2023; 2023-11/119).

Methods

New Zealand rabbits were placed individually on the CT device (Siemens, Somatom Sensation 64, Erlangen, Germany) in a prone position and symmetrically. CT device parameters were: physical detector collimation(32 x 0.5 mm), final section collimation (64 x 0.5mm), section thickness (0.50 mm), portal rotation time (330 msec), kVp (130), mA (300), resolution (512 x 512 pixels), resolution range (0.92 x 0.92).7,15 The images that were obtained were saved onto the hard disk in DICOM format. CT images were transferred to the MIMICS 21.0 (The Materialize Group, Leuven, Belgium) software program and threshold HU (Hansfield Unit) values were 350-1000 to distinguish bone tissues from other tissues. Then, separate 3D models of the bones forming the cavum pelvis (ossa coxae and os sacrum) were created using different tools of the program (region growing, edit mask, 3D calculation).

Morphometric Measurements

In this study, morphometric measurements were performed on the pelvic cavity and os coxae, 3D models of which were created. Volume and surface areas, diameter, and angle values were obtained from these models (Figure 1-3). Measurement points of the pelvis specified in the relevant literature were used.[5,14] The measurement points and their descriptions were given in Table 1.

Dissection Process

After CT imaging, the dissection of the pelvis was performed in New Zealand rabbits. First, using a surgical knife, the skin and muscles were carefully removed, leaving minimal soft tissue attachment to the bones. Then, the caudal border of

the last lumbar vertebra and the cranial border of vertebrae caudales and the sacrum were disconnected, and the caput ossis femoris was separated from the acetabulum and the dissection of the pelvic bones was completed. After these procedures, the pelvic bone was photographed (Nikon D5200, 18-55 Vr), and the anatomical structures were named (Figure 4). Nomina Anatomica Veterinaria (NAV 2017)[16] was used to name anatomical structures.

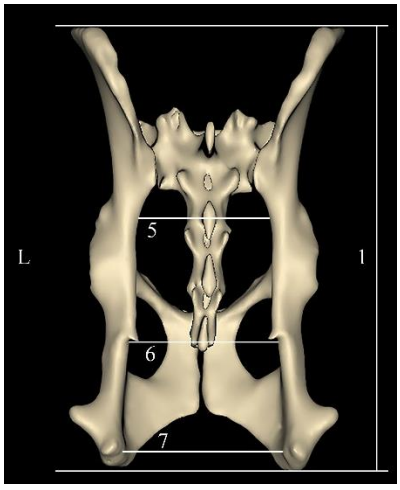

Figure 1. Measurements on facies dorsalis of pelvis.

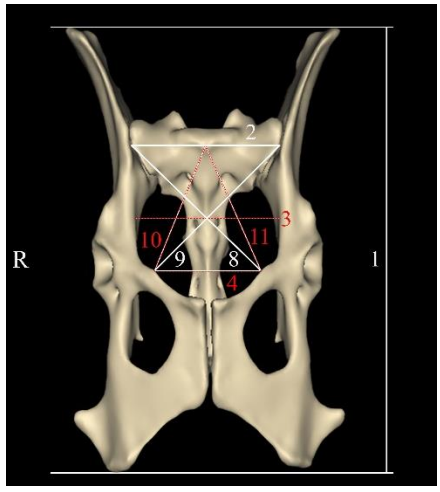

Figure 2. Measurements on facies ventralis of pelvis.

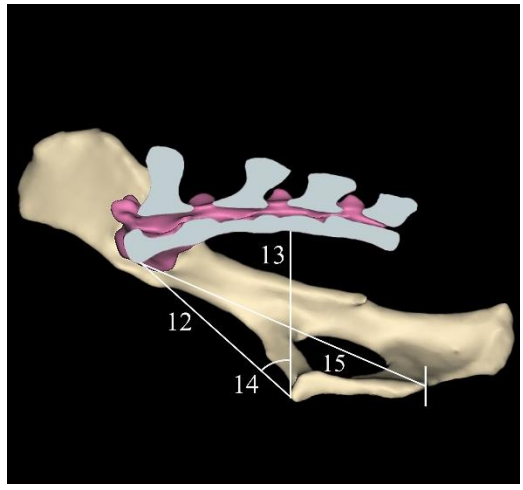

Figure 3. Measurements on lateral view of pelvis.

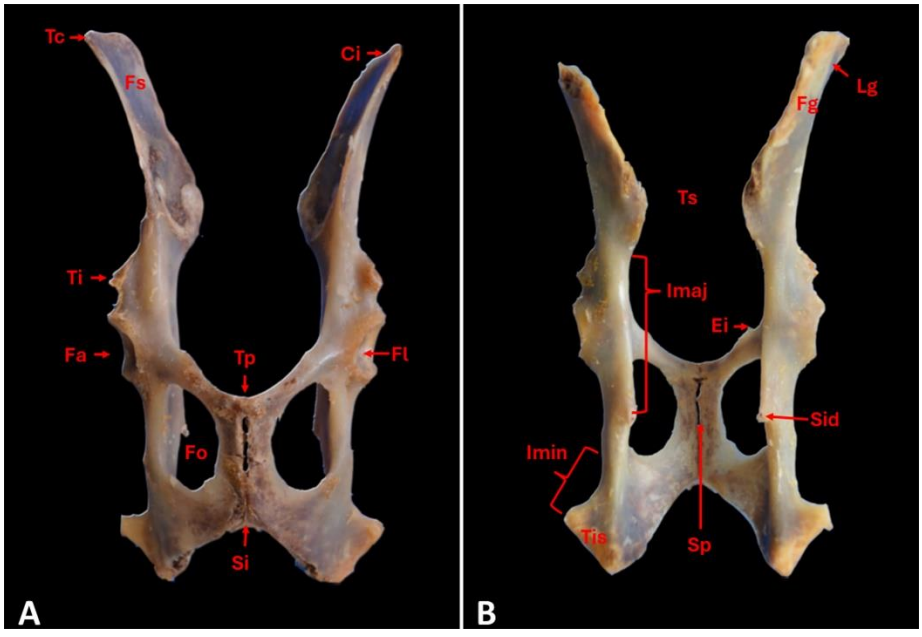

Figure 4. Os coxae in the New Zealand rabbit. **A: Ventral view**, Ti: Tuberositas iliaca, Fa: Fossa acetabuli, Fl: Facies lunata, Tc: Tuber coxae, Ci: Crista iliaca, Fo: Foramen obturatum, Fs: Facies sacropelvina, Tp: Tuberculum pubicum, Si: Symphysis ischiadica, **B: Dorsal view**, Fg: Facies glutea, Lg: Lineae gluteae, Ts: Tuber sacrale, Ei: Eminentia iliopubica, Sid: Spina ischiadica dorsale, Tis: Tuber ischiadicum, Imaj: Incisura ischiadica major, Imin: Incisura ischiadica minor, Sp: Symphysis pelvina

Table 1. Osteometric parameters and measuring points.[5,14]

Parameter	Abbreviation	Osteometric Parameters	Measuring Points
1	GL	Greatest length	Cranial border of ilia (margo iliocranialis)-most caudal points of the ischia
2	DTD	Dorsal transverse diameter	The distance between ends of two ala ossis sacri
3	ITD	Intermediary transverse diameter	The distance between the two tuberculum m.psoas minor.
4	VTD	Ventral transverse diameter	The distance between the two iliopubic eminence.
5	CrTD	Cranial transverse diameter	The distance between the front ends of two incisura ischiadica major
6	MTD	Medial (bispinous) transverse diameter	The distance between two spina ischiadica
7	CaTD	Caudal (bituberous) transverse diameter	The distance between the interior faces of two tuber ischiadicum (diameter between ischial tuberosities)
8	ROD	Right oblique diameter	The distance between the right sacroiliac joint and the left iliopectineal eminence
9	LOD	Left oblique diameter	The distance between the left sacroiliac joint and the right iliopectineal eminence
10	RSD	Right sacrocotyloid diameter	The distance between the promontory of the sacrum and the right iliopectineal eminence
11	LSD	Left sacrocotyloid diameter	The distance between the promontory of the sacrum and the left iliopectineal eminence
12	CV	Conjugata vera	The distance between the cranial end of the pelvic symphysis and the promontory of the sacrum
13	VD	Vertical diameter	The distance between the cranial end of pelvic symphysis and the ventral surface of the sacrum
14	PI	Pelvic inclination	The angle between the conjugate and vertical diameters
15	CD	Conjugate diagonalis	The distance between the caudal end of the pelvic symphysis and the promontory of the sacrum

Statistical Analysis

In the study, the analysis of morphometric data obtained from bones was performed using the SPSS 21.0 (IBM SPSS Corp., Armonk, NY, USA) statistical package program. The conformity of the variables to normal distribution (histogram and probability graphs) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk tests) were examined. As a result, the data shows a normal distribution. Paired samples t test was used for statistical comparisons of right and left values of bones, and Independent Samples t test was used for comparisons of male and female rabbits. The relationship between measurements was determined using Pearson's correlation analysis.7 Data are expressed as means ± standard deviation (SD). $P < .05$ was accepted statistically significant.

RESULTS

In the rabbit, the pelvic cavity was formed by the os coxae, which connects with symphysis pubica in the ventral midline, and the sacrum, which articulates dorsomedially through the iliosacral joints and first caudal vertebrae. Os coxae was formed by the union of three bones, os ilium located in the most cranial part, os ischii located in the dorso-caudal part and os pubis located in the ventro-caudal part. The acetabulum was located at the junction of these three bones. The articular surface (facies lunata) was crescent-shaped and the ends of this crescent were extending and turning into a foramen. The two bones were joined in the ventral midline by the symphysis pubica. The gluteal surface of the os ilium was divided by linea gluteae, which was a thick line. On the side facing the pelvic cavity, there was also a facies auricularis that would joint with the sacrum. There was a sharp crista iliaca on the cranio dorsal edge of the os ilium. Os ischii formed the dorso-caudal part of os coxae. The dorsal wide edge of the bone extended towards the acetabulum and raised towards the tuber ischiadicum. In addition, the os ischii was also shaping the spina ischiadica at the level of the acetabulum and the incisura ischiadica minor in an inverted v shape. Eminentia iliopubica was visible towards the medial part of the pecten ossis pubis.

Morphometric measurements made on the 3D model of the pelvis in New Zealand rabbits are given in Table 2. When pelvimetric measurements were compared in female and male rabbits, all values except pelvic inclination were found

to be greater in females. It was determined that there was a statistical difference between female and male rabbits in greatest length, dorsal transverse diameter, right and left oblique diameter, right and left sacrocotyloid diameter, and conjugata vera at $P < .05$ and there was a statistical difference in intermediary, ventral, cranial, transverse, caudal and vertical diameters at $P < .001$. But pelvic inclination did not show a statistical difference ($P > .05$). When comparing the right and left oblique diameter and sacrocotyloid diameter values of female and male rabbits, no statistical difference was found ($P > .05$).

Table 2. Morphometric measurement values of the pelvic cavity obtained from 3D reconstruction

Measurement	Gender	Mean	SD	Minimum	Maximum	*P*
Greatest length (mm)	Female	86.32	2.94	81.95	91.65	.031*
	Male	83.35	2.72	78.25	86.34	
Dorsal transverse diameter (mm)	Female	28.23	1.85	24.40	30.99	.002*
	Male	25.56	1.53	22.39	28.03	
Intermediary transverse diameter (mm)	Female	27.86	1.11	26.57	29.55	.000**
	Male	23.73	0.91	22.16	25.49	
Ventral transverse diameter (mm)	Female	21.83	1.50	20.19	24.38	.000**
	Male	17.34	1.08	16.01	20.02	
Cranial transverse diameter (mm)	Female	25.85	0.85	24.99	27.12	.000**
	Male	22.27	0.94	20.79	23.76	
Medial (bispinous) transverse diameter (mm)	Female	23.92	0.98	22.53	25.23	.000**
	Male	19.90	1.07	18.33	22.03	
Caudal (bituberous) transverse diameter (mm)	Female	29.70	2.31	25.66	33.32	.000**
	Male	23.01	1.62	19.61	24.84	
Right oblique diameter (mm)	Female	35.26	1.84	32.89	38.30	.012*
	Male	32.95	1.86	29.07	35.22	
Left oblique diameter (mm)	Female	36.17	1.86	33.07	39.28	.003*
	Male	33.44	1.65	29.83	35.44	
Right sacrocotyloid diameter (mm)	Female	27.68	1.26	25.64	29.84	.028*
	Male	26.31	1.31	24.03	28.16	
Left sacrocotyloid diameter (mm)	Female	27.46	1.06	25.99	29.15	.044*
	Male	26.21	1.61	23.02	28.46	
Conjugata vera (mm)	Female	33.10	1.57	29.97	35.66	.003*
	Male	30.74	1.56	28.30	33.53	
Vertical diameter (mm)	Female	25.61	1.28	23.15	27.35	.000**
	Male	22.87	1.02	21.69	24.79	
Pelvic inclination (°)	Female	55.37	6.19	45.52	64.99	.186
	Male	58.75	4.68	53.38	68.63	
Conjugate diagonalis (mm)	Female	52.12	2.10	48.80	55.94	.040*
	Male	49.36	1.60	47.23	51.97	

*$P < .05$, $P < .001$; independent samples t test

Table 3 presents the volume and surface area of os coxae obtained from 3D reconstruction. The data reveals that there is no significant difference in the volume and surface area of right and left os coxae between male and female rabbits ($P > .05$).

When the correlation of data obtained from female and male rabbits is examined in Table 4, there is a statistically significant correlation between all data except MTD, CaTD, and PI values in male rabbits, and CaTD in female rabbits.

Table 3. Os coxae volume and surface area obtained from 3D reconstruction

Gender	Measurement	Mean	SD	Minimum	Maximum	*P**
Female	Left os coxae volume (mm^3)	4253,43	275,60	3792,27	4594,42	.741
	Right os coxae volume (mm^3)	4246,52	299,38	3825,9	4718,08	
	Left os coxae surface area (mm^2)	4701,24	351,49	4047,47	5026,17	.059
	Right os coxae surface area (mm^2)	4671,89	362,03	4033,57	5036,49	
Male	Left os coxae volume (mm^3)	3796,62	223,76	3325,61	4019,64	.709
	Right os coxae volume (mm^3)	3791,51	206,45	3356,16	3989,44	
	Left os coxae surface area (mm^2)	4364,63	358,55	3805,35	4844,88	.424
	Right os coxae surface area (mm^2)	4378,23	350,52	3828,71	4788,24	

*$P < .05$; paired samples t test

Table 4. Correlation analyses of the pelvic cavity

	GL	DTD	IDT	VTD	CrTD	MTD	CaTD	ROD	LOD	RSD	LSD	CV	VD	PI	CD
GL	1	0.810**	0.474	0.208	0.338	-0.147	0.327	0.876**	0.888**	0.765*	0.725*	0.787**	0.558	0.128	0.602
DTD	0.757*	1	0.611	0.405	0.676*	0.055	0.528	0.738*	0.949**	0.570	0.594	0.690*	0.360	0.469	0.588
IDT	0.539	0.639*	1	0.859**	0.856**	0.457	0.544	0.186	0.600	0.042	0.123	0.166	0.375	0.279	0.296
VTD	0.362	0.501	0.715*	1	0.659*	0.240	0.444	0.008	0.431	-0.157	-0.110	-0.064	0.280	0.441	0.180
CrTD	0.463	0.463	0.803**	0.253	1	0.612	0.603	0.130	0.551	-0.011	0.115	0.175	0.061	0.459	0.174
MTD	0.257	0.160	0.644*	0.270	0.661*	1	0.161	-0.333	-0.095	-0.266	-0.127	-0.063	0.106	-0.171	-0.097
CaTD	-0.027	0.178	0.576	0.547	0.341	0.630	1	0.325	0.531	0.173	0.261	0.097	0.229	0.441	0.151
ROD	0.724*	0.788**	0.791**	0.752*	0.485	0.488	0.308	1	0.866**	0.943**	0.922**	0.868**	0.568	0.089	0.780**
LOD	0.669*	0.902**	0.738*	0.605	0.482	0.350	0.253	0.929**	1	0.723*	0.735*	0.760*	0.521	0.356	0.721*
RSD	0.372	0.690*	0.741*	0.641*	0.550	0.400	0.267	0.846**	0.880**	1	0.972**	0.927**	0.626	-0.202	0.784**
LSD	0.676*	0.757*	0.918**	0.714*	0.702*	0.664*	0.478	0.950**	0.891**	0.843**	1	0.887**	0.618	-0.179	0.844**
CV	0.148	0.455	0.459	0.785**	-0.048	0.181	0.362	0.730*	0.685*	0.729*	0.607	1	0.586	-0.150	0.714*
VD	0.064	0.168	0.296	0.548	-0.087	0.445	0.344	0.597	0.448	0.505	0.505	0.831**	1	-0.398	0.689*
PI	0.214	0.099	-0.222	-0.573	0.026	-0.041	-0.055	-0.319	-0.158	-0.476	-0.249	-0.646*	-0.621	1	-0.115
CD	0.382	0.775**	0.385	0.272	0.327	-0.214	-0.195	0.514	0.734*	0.708*	0.460	0.393	0.006	-0.147	1

*$P < .05$. ** $P < .01$; Gray cells in the table are data for male New Zealand rabbits.

DISCUSSION

The pelvis is crucial for stabilizing the spine and transferring movement through the sacrum to the rest of the body. The bones that make up the pelvis protect the organs located in this space and play an important role in birth. Pelvic dimensions play a crucial role in birth and reproductive processes.12,17 Moreover, pelvic bones can be used as an important parameter for gender determination.18 It is crucial to create three-dimensional reconstructions of bones because it allows surgeons to plan operations more accurately and examine the models from any desired angle.6 The reproducibility of the modeling method used, the ability to produce scientifically proven accurate results, and the ability to make measurements are among the reasons that increase its clinical importance.7,19 In this study, three-dimensional modeling of the pelvis was performed on CT images of New Zealand rabbits of the same age and different genders. Diameter and angle measurements were made on this model and the anatomical formations of the bones forming the pelvis were named by dissection.

El-Ghazali and El-Behery10 state that the os coxae in the rabbit consist of three bones that meet in the acetabulum and that the articulation surface with the femur is crescent-shaped. They also state that the wing of the os ilium is paddle-like, that it has a C-shaped auricular surface (Facies auricularis) for articulation with the wing of the sacrum on the surface facing the pelvis, that the crista iliaca is thin, and that this thinness continues the lateral and medial edges. Some literature states that there is an accessory bone called os acetabuli in the rabbit, which helps to form the acetabulum together with os ilium and os ischii.20,21 While the presented study is compatible with the data of El-Ghazali and El-Behery, os acetabuli was not found. It was determined that the acetabulum had a crescent-shaped articular surface and the end parts of the articular surface expanded and turned into a fovea.

In their comparative study on female and male New Zealand rabbits, Özkadif et al.[5] found a statistical difference between dorsal transverse, cranial transverse, caudal transverse, medial transverse, right oblique and left oblique diameters, conjugate vera, conjugate diagonalis, vertical diameter and inclinatio pelvis. They stated that there was no difference in terms of intermediate transverse, ventral transverse, right sacrocotyloid and left sacrocotyloid diameter values. In the presented study, while only pelvic inclination showed no difference, a statistical difference was detected in other diameter measurements. It was suggested that the difference in results between the two studies might have been due to the dissimilar ages of the rabbits. In a study conducted by Özkadif et al.[5], it was found that there was no significant difference between the right and left oblique diameter as well as the sacrocotyloid diameter values in female and male rabbits. Similar results were obtained in the presented study.

According to the literature, there was a greater distance between the symmetrical parts of the pelvis and a larger angle between the arcus ischiadicus in female animals.2 The presented study is compatible with the literature knowledge. It is also observed that the measured diameter values were larger in female rabbits compared to males. It is believed that the larger size of the female pelvic cavity is due to the presence of organs of the urinary system and the birth canal required for reproduction.

In osteometric diameter measurements of the pelvis using radiological imaging on cats18,22, Kangal dogs23, gazelle14 and red fox12, it was stated that the values in males were higher than in females. In New Zealand rabbits, females had higher values in all pelvic diameter measurements except the intermediary transverse diameter.5 The presented study concluded that pelvic diameters were higher in female rabbits than in males, excluding pelvic inclination.

In conclusion, pelvis data obtained from 3D reconstructions using CT images in healthy New Zealand rabbits revealed morphometric differences of the pelvic cavity in females and males, and volume and surface area data were shared for the first time. The markings on the pictures are expected to aid researchers in comprehending the anatomical structure of the area. The acquired data could be used in rabbit sex discrimination, would assist physicians in diagnosing patients in the clinic, serve as a reference for clinical practices, and establish the foundation for new research.

Ethics Committee Approval: Ethics committee approval was obtained from Selçuk University Faculty of Veterinary Medicine Experimental Animal Production and Research Center Ethics Committee (Date: 02.11.2023, Number: 2023-11/119).
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