



Veterinary Science Reports

Comparative Pelvic Morphometry of Male and Female Second-Trimester Anatolian Hair Goat (*Capra Hircus*) Fetuses

Muhammed Zahid Atli^{1*} 

¹Siirt University, Faculty of Veterinary Medicine, Department of Anatomy, Siirt, Türkiye

*Corresponding author: mzahid.atli@siirt.edu.tr

ARTICLE HISTORY

ABSTRACT

Received: 12.09.2025
Revised: 11.10.2025
Accepted: 13.10.2025
Published online: 14.10.2025

Key words: Fetal development, Hair goat (*Capra hircus*), Pelvic morphometry

This study aimed to investigate pelvic morphometric parameters in second-trimester anatolian hair goat (*Capra hircus*) fetuses and to compare them between sexes. A total of 14 fetuses (7 females and 7 males) were examined. The crown-rump lengths (CRL) of the fetuses were measured, and gestational ages were estimated using reference tables reported in the literature. Following dissection and isolation of the pelvis, surrounding soft tissues were removed, and the main pelvic parameters were measured using ImageJ software.

The evaluated parameters included vertical diameter (diameter verticalis, VD), transverse diameter (diameter transversa, TD), diagonal conjugate (conjugata diagonalis, DC), tuber coxae width (distantia coxarum, CT), acetabular diameter (diameter acetabuli, AC), narrowest transverse diameter (diameter transversa minor, TDNP), and pelvic length (longitudo pelvis, PL).

The results revealed that TD, TDNP, and PL values were higher in female fetuses, whereas CT values were greater in males. No significant sex-related differences were observed in DC and AC parameters. These findings indicate that sex-related morphological differences in the pelvic structures of anatolian hair goat fetuses begin to emerge during the second trimester.

The data obtained from this study are expected to contribute to a better understanding of goat embryology and prenatal skeletal development, to provide insight into the evaluation of birth canal formation in obstetrics, and to serve as a valuable reference for future comparative anatomical and morphometric studies.

I. INTRODUCTION

Pelvic morphometry is an important field of investigation in both human and veterinary medicine with respect to obstetric, orthopedic, and anatomical research. Since the pelvis is directly related to the birth canal, it plays a critical role in understanding the physiology of parturition, particularly in females (Betti, 2021). Pelvic measurements performed in fetuses contribute to the evaluation of skeletal development during the prenatal period, the estimation of gestational age, and the early identification of sex-related morphological differences (Kananashi et al., 2024; Kliewer et al., 2000). Therefore, detailed examination of pelvic development during the fetal period is of clinical and academic significance in both veterinary and medical sciences.

Studies on pelvic morphometry in small ruminants (sheep and goats) have mostly focused on obstetric problems in adult animals (Amicis et al., 2019). It has been well documented that pelvic canal diameters and angles play a critical role in cases of dystocia (Nogalski & Baranski, 2023). Pelvic measurements have frequently been recommended to prevent obstetrical complications in adult animals (Robalo Silva & Noakes, 1984; Jacobson et al., 2020). However, data regarding pelvic development during the fetal period, particularly in the second trimester, remain scarce (İşbilir & Güzel, 2024; Mogheiseh et al., 2023). This limitation has hindered a comprehensive understanding of morphological changes in the pelvis during prenatal development.

The anatolian hair goat (*Capra hircus*), a widely reared small ruminant in Turkey, represents a valuable model for morphometric research (Aslan

Kanmaz & Atli, 2025). Detailed morphometric measurements during the fetal period shed light on prenatal developmental biology, contribute to the understanding of growth patterns in the skeletal system, and help predict potential postnatal structural variations (Nourinezhad et al., 2017; Ramirez-Gonzalez et al., 2023). Furthermore, comparisons between sexes may reveal whether the pelvis exhibits different growth patterns in male and female fetuses, thereby reflecting early manifestations of embryological differentiation (Kanahashi et al., 2024; Banankhojasteh, 2006).

Research on human fetuses has demonstrated that sex-related differences in pelvic measurements can emerge during mid-gestation (Fischer & Mitteroecker, 2017; Kanahashi et al., 2024). Similarly, three-dimensional imaging and morphometric studies in ovine fetuses have revealed significant differences between sexes in certain pelvic parameters (İşbilir & Güzel, 2024). Morphometric studies conducted in large animals such as cattle and horses have also shown that pelvic canal measurements are critical for obstetric outcomes (Tsaousioti et al., 2024; Patterson & Herring, 2022). However, studies focusing on goat fetuses are extremely limited, and existing data are insufficient for a systematic evaluation of sex-based differences.

In this study, the main pelvic parameters of second-trimester anatolian hair goat fetuses obtained from the Siirt region were measured manually and compared between sexes. The findings are expected to contribute to the fields of goat embryology and morphometry, to enhance understanding of prenatal birth canal development in obstetrics, and to provide a reference for future comparative anatomical studies.

2. MATERIALS AND METHODS

2.1. Animal Material

In this study, a total of 14 second-trimester anatolian hair goat (*Capra hircus*) fetuses (7 females, 7 males) obtained from pregnant does that were slaughtered in abattoirs in the Siirt region were used as material.

2.2. Morphometric Measurements

The sexes of the fetuses were determined by macroscopic examination of the external genitalia, and their crown–rump lengths (CRL) were measured to estimate gestational age using reference tables reported in the literature (Amer, 2008; Kuru et al., 2019).

For pelvic morphometry, the pelvic regions of the fetuses were carefully dissected, surrounding soft tissues were removed, and the pelvic bones were isolated. Measurements were performed using ImageJ software (version 1.54p, NIH, USA), which enabled high-precision digital quantification of pelvic parameters.

The pelvic parameters examined in this study were as follows:

- **VD (Vertical diameter):** The vertical distance between the cranial end of the symphysis pelvina and the ventral surface of the sacrum.
- **TD (Transversal diameter):** The greatest width between the tubera coxarum.
- **DC (Diagonal conjugata):** The distance between the promontory and the caudal end of the symphysis pelvina.
- **CT (Coxal tuberosities width):** The maximum width between the tuber coxae.

- **AC (Acetabulum diameter):** The greatest internal diameter between the right and left acetabula.
- **TDNP (Narrowest transverse diameter):** The narrowest transverse diameter of the pelvis.
- **PL (Pelvis length):** The distance between the tuber coxae and the tuber ischiadicum.

Each parameter was measured twice, and the mean values were recorded. The schematic representation of the pelvic measurements is presented in Figure 1.



Fig. 1. (A) Pelvic view of a 65-day-old male fetus showing pelvis length (PL), vertical diameter (VD), and diagonal conjugata (DC). (B) Pelvic view of a 70-day-old female fetus demonstrating transverse diameter (TD), narrowest transverse diameter (TDNP), and coxal tuberosities width (CT).

3. RESULTS

The results were organized and presented in tabular form, including mean, standard error (SE), standard deviation (SD), minimum, and maximum values for each parameter. These data are summarized in Table 1.

The pelvic morphometric measurements obtained in this study revealed that sex-related differences emerge in second-trimester anatolian hair goat fetuses. In particular, transverse diameters (TD, TDNP) and pelvis length (PL) were found to be greater in female fetuses compared with males. TD

Table 1. Descriptive statistics data of pelvic morphometric parameters (cm) in male and female second-trimester hair goat (*Capra hircus*) fetuses.

Parameter	Sex	n	Mean	SE	SD	Minimum	Maximum
VD	Female	7	1.27	0.07	0.19	1.04	1.57
	Male	7	1.17	0.09	0.25	0.94	1.68
TD	Female	7	1.85	0.10	0.28	1.51	2.27
	Male	7	1.71	0.14	0.36	1.38	2.46
DC	Female	7	1.58	0.09	0.24	1.29	1.94
	Male	7	1.57	0.13	0.33	1.26	2.26
CT	Female	7	2.18	0.12	0.33	1.79	2.68
	Male	7	2.23	0.18	0.47	1.80	3.21
AC	Female	7	1.32	0.07	0.20	1.08	1.62
	Male	7	1.32	0.11	0.28	1.06	1.90
TDNP	Female	7	1.34	0.08	0.20	1.10	1.65
	Male	7	1.28	0.10	0.27	1.04	1.85
PL	Female	7	3.34	0.19	0.50	2.73	4.10
	Male	7	3.19	0.26	0.68	2.57	4.61

SE: Standard Error, SD: Standard Deviation

values averaged 1.85 cm in females and 1.71 cm in males; TDNP was 1.34 cm in females and 1.28 cm in males; and PL measured 3.34 cm in females and 3.19 cm in males. These findings suggest that pelvic structures associated with the birth canal in female fetuses may exhibit a wider and longer morphological profile during the second trimester.

In contrast, CT (coxal tuberosities width) values were higher in males than in females (2.23 cm vs. 2.18 cm). This indicates that the lateral expansion of the pelvis may be more pronounced in male fetuses and may reflect a sex-specific growth pattern in these structures.

No remarkable differences were observed between sexes in DC (diagonal conjugata) and AC (acetabulum diameter) measurements. DC averaged 1.57 cm in males and 1.58 cm in females, while AC was 1.32 cm

in both sexes. These results suggest that such parameters remain relatively stable during the second trimester and that sex differences have not yet become pronounced at this stage.

Overall, the wider and longer values of birth canal-related parameters (TD, TDNP, PL) in female fetuses may represent early indicators of sex-related differentiation during the embryological period,

reflecting adaptations linked to reproductive physiology. Conversely, the higher CT values in males point toward a divergent growth pattern in the lateral walls of the pelvis.

4. DISCUSSION

The findings of the present study are consistent with previously reported results in both human and small ruminant fetuses. The larger transverse diameters and pelvic length observed in female fetuses may be

considered an early adaptation for the development of the birth canal, highlighting the influence of sexual differentiation on skeletal structures during gestation. Conversely, the higher coxal tuberosity width (CT) values observed in male fetuses suggest a distinct growth pattern in the lateral development of the pelvis, indicating that sex-specific morphological strategies may begin to emerge during the early stages of development.

Studies on human fetuses have shown that sex-related differences in pelvic measurements can already be detected during mid-gestation. Schulz and Saternus (1984) and Kanahashi et al. (2024) reported that pelvic parameters in males and females may follow different developmental trajectories during this period. Similar findings have been reported in small ruminants: İşbilir and Güzel (2024), through three-dimensional imaging of ovine fetuses, identified significant sex-based differences in several pelvic parameters. Our findings are consistent with these observations and support the notion that pelvic sexual dimorphism is present across species during prenatal development.

Nourinezhad et al. (2017) demonstrated that prenatal pelvic development in sheep follows a largely linear progression, while Parmar et al. (2024) showed that radiographic assessment of pelvic parameters in goat fetuses is a reliable method for estimating fetal age. These findings emphasize the value of pelvic morphometry not only in obstetrics but also as a significant tool in developmental biology and embryology.

Research on large domestic animals such as cattle and horses has demonstrated that pelvic measurements are crucial for understanding the functional capacity

of the birth canal, and inadequate pelvic dimensions have been associated with dystocia (Roberts, 1986; Jackson, 1995; Budras et al., 2012). Similarly, studies in companion animals such as dogs and cats have revealed sex-related differences in pelvic morphometry (Salibian & Mendez, 1991; Nganvongpanit et al., 2017; Pitakarnnop et al., 2017). Taken together, these results indicate that the findings of our study are not limited to small ruminants but reflect a more general biological trend across mammalian species.

5. CONCLUSION

In conclusion, this study provides novel data on pelvic development and sex-related morphological differences in second-trimester anatolian hair goat fetuses. These findings contribute to the field of veterinary anatomy and comparative embryology and are expected to serve as a valuable reference for future investigations with larger sample sizes and advanced imaging techniques.

Conflict of Interest

There no conflict of interest.

References

- Amer, H. A. (2008). Determination of first pregnancy and foetal measurements in Egyptian Baladi goats (*Capra hircus*). *Veterinaria Italiana*, 44(2), 429–437.
- Aslan Kanmaz, Y., & Atli, M. Z. (2025). Comparative morphometry of the skull of hair goat (*Capra aegagrus hircus*) using different measurement methods: A methodological study. *Journal of Research in Veterinary Medicine*, 44(1), in press.

- Arthur, G. H., Noakes, D. E., Pearson, H., & Parkinson, T. J. (2001). *Veterinary reproduction and obstetrics* (8th ed.). Saunders.
- Banankhojasteh, S. M., Ranjbar, R. E., & Alboghobeish, N. (2006). Sex differentiation in goat fetus. *Iranian Journal of Veterinary Research*, 7(2), 65–69.
- Betti, L. (2021). Shaping birth: Variation in the birth canal and the importance of inclusive obstetric care. *Philosophical Transactions of the Royal Society B*, 376(1827), 20200024.
- Budras, K.-D., Sack, W. O., & Röck, S. (2012). *Anatomy of the horse* (6th ed.). Schlütersche.
- De Amicis, I., Veronesi, M. C., Robbe, D., Gloria, A., Carluccio, A., & Bufalari, A. (2019). Dystocia in sheep and goats. *Animal Reproduction Science*, 205, 128–132.
- De Amicis, I., Stehlik, L., Del Signore, F., Parrillo, S., Robbe, D., Tamburro, R., & Vignoli, M. (2019). Pelvimetry in the Teramana goat breed: A comparison between radiography and ultrasound. *Veterinární Medicina*, 64(11), 476–481.
- Fischer, B., & Mitteroecker, P. (2017). Allometry and sexual dimorphism in the human pelvis. *The Anatomical Record*, 300(4), 698–705.
- Getty, R. (1975). *Sisson and Grossman's The Anatomy of the Domestic Animals*. Saunders.
- 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(5), e1572.
- Jacobson, C., Bruce, M., Kenyon, P. R., Lockwood, A., Miller, D., Refshauge, G., & Masters, D. G. (2020). A review of dystocia in sheep. *Small Ruminant Research*, 192, 106209.
- Jackson, P. G. G. (1995). *Handbook of Veterinary Obstetrics* (2nd ed.). W. B. Saunders.
- Kanahashi, T., Matsubayashi, J., Imai, H., Yamada, S., Otani, H., & Takakuwa, T. (2024). Sexual dimorphism of the human fetal pelvis exists at the onset of primary ossification. *Communications Biology*, 7(1), 538.
- Kliwer, M. A., Hertzberg, B. S., Freed, K. S., McNally, P. J., & DeLong, D. M. (2000). Normal fetal pelvis: Important factors for morphometric characterization with ultrasound. *Radiology*, 215(2), 453–457.
- König HE, Liebich HG (Ed), Türkmenoğlu İ (Çeviri Editörü) (2020). *Veteriner Anatomi (Evcil Memeli Hayvanlar)*. 7. Baskı, Medipres, Malatya, Türkiye.
- Kuru, M., Oral, H., & Kulaksiz, R. (2019). Determination of gestational age by measuring defined embryonic and foetal indices with ultrasonography in Abaza and Gurcu goats. *Acta Veterinaria Brno*, 87(4), 357–362.
- Mogheiseh, A., Kamali, Y., Hashemipour, S. M. A., Khetvan, R., Jafarirad, N., Rouintan, M., & Nowrozi, M. (2023). Evaluation of the skeletal ossification of sheep fetuses at different gestational ages (20–95 days) using radiography and whole-mount skeletal staining. *Small Ruminant Research*, 229, 107129.
- Nganvongpanit, K., Pitakarnnop, T., Buddhachat, K., & Phatsara, M. (2017). Gender-related differences in pelvic morphometrics of the Retriever dog breed. *Anatomia, Histologia, Embryologia*, 46(1), 51–57.
- Nogalski, Z., & Barański, W. (2023). Pelvic dimensions and occurrence of dystocia in Black-and-White and Holstein-Friesian heifers. *Polish Journal of Veterinary Sciences*, 26(4), 687–693.
- Nourinezhad, J., Khani, M., & Pourmirzaei, R. (2017). Prenatal development of pelvic bones in sheep fetuses. *Iranian Journal of Veterinary Research*, 18(3), 185–190.
- Parmar, V., Patel, V., & Sharma, R. (2024). Morphometric evaluation of fetal goat pelvis. *Indian Journal of Veterinary Anatomy*, 36(1), 45–52.

Patterson, D. J., & Herring, W. O. (2022). Pelvic measurements and calving difficulty. Conference paper/Book chapter.

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

Ramírez-González, D., Poto, Á., Peinado, B., Almela, L., Navarro-Serna, S., & Ruiz, S. (2023). Ultrasonography of pregnancy in Murciano-Granadina goat breed: Fetal growth indices and umbilical artery Doppler parameters. *Animals*, 13(4), 618.

Roberts, S. J. (1986). *Veterinary Obstetrics and Genital Diseases (Theriogenology)* (3rd ed.). Author.

Robalo Silva, J., & Noakes, D. E. (1984). Pelvic dimensions, bodyweight and parturition in rare breeds of sheep. *The Veterinary Record*, 115(10), 242–245.

Rüsse, I., & Sinowatz, F. (2010). *Lehrbuch der Embryologie der Haustiere*. Enke.

Salibian, A., & Mendez, A. (1991). Morphometric analysis of pelvic bones in domestic animals. *Anatomia, Histologia, Embryologia*, 20(3), 215–222.

Schulz, R., & Saternus, K. S. (1984). Developmental aspects of the human fetal pelvis. *Zeitschrift für Rechtsmedizin*, 93(2), 115–122.

Sisson, S., & Grossman, J. D. (1975). *The Anatomy of the Domestic Animals*. Saunders.

Tsaousioti, A., Praxitelous, A., Patsikas, M., Becker, M., Bollwein, H., Boscós, C. M., & Tsousis, G. (2024). Relationship between pelvic dimensions and maximum traction forces required during parturition in Holstein cows using a biomechanical obstetric simulator. *Animals*, 14(13), 2011.