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Research Article

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Macroscopic Development of the Scapula in Sheep (*Ovis aries*) During the Last Two Trimesters of Gestation

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ABSTRACT

This study investigated the morphological and morphometric development of the fetal scapula in sheep (*Ovis aries*). Hamdani crossbred sheep fetuses, obtained from slaughtered healthy animals in Siirt province, were used for the study. Using a formulation, gestational ages were calculated from crown-anus distance (CRL) measurements. Following careful dissection, morphometric analyses of scapula samples were conducted utilizing ImageJ software. Key measured parameters included diagonal length (DL), dorsal scapular width (SW-d), medial scapular width (SW-m), ventral scapular width (SW-v), scapular spine length (SSL), scapular cartilage width (SCW), scapular cartilage length (SCL), fossa supraspinata width (FSSW), fossa infraspinata width (FISW), and fossa subscapularis width (FSW). Results demonstrated significant and progressive increases in scapular bone dimensions and specific morphological regions with advancing fetal age. These findings will contribute significantly to understanding prenatal ossification processes and skeletal growth dynamics in sheep. From a clinical perspective, these data will provide reference values for veterinary orthopedic evaluations and will support further studies in animal husbandry and anatomical research.

1. INTRODUCTION

Sheep (*Ovis aries*) have historically held significant economic, social, and cultural roles within agriculture and livestock activities. They are widely farmed globally, primarily for products such as meat, milk, wool, and leather, making them economically important animals (Gebremedhin et al., 2020). Recent advances in veterinary medicine and animal husbandry have significantly improved methods for monitoring and enhancing sheep health. These methods facilitate healthy growth, enable early disease detection, and thus substantially contribute to improved productivity and animal welfare (Silva et al., 2022; Abe et al., 2024).

The skeletal system is critically important for mobility and functional health in sheep, as in all vertebrate species. Bones serve as muscle attachment points, enabling movement, and providing fundamental structural support to the body (König & Liebich, 2020). Among these bones, the scapula (shoulder blade) is especially crucial due to its role in determining the range of motion and weight-bearing capacity of the forelimbs. It enhances movement efficiency and stabilizes the limbs by offering key muscle attachment sites. Therefore, understanding normal morphological and developmental features of the scapula is vital for orthopedic interventions, trauma management, and accurate assessment of anatomical variations (Akçasız et al., 2024).

Bone development during the fetal period is a complex process beginning in the embryonic stage and continuing until birth. This process encompasses ossification, cellular differentiation, and mineralization phases (Hall, 1988). Particularly in the second and third trimesters, rapid bone development and differentiation occur. Significant anatomical and histological changes are observed in critical bones like the scapula during these stages (Hall, 1988; Fisher, 1998). Understanding the details of ossification speed and shaping processes during these periods is essential for comprehending potential developmental anomalies and skeletal growth issues (Ogden & Philips, 1983). Understanding developmental processes during the fetal period can enhance early diagnosis and intervention capabilities, thereby reducing economic losses and improving herd health.

This study aims to thoroughly examine the morphological and morphometric parameters of scapular development during fetal stages in sheep. These parameters include bone size, shape, proportions of various regions, ossification levels, and morphological variations. The findings of this study are expected to clarify critical periods of fetal bone development, provide valuable insights for clinical veterinary practices, and serve as a foundation for future research. It is anticipated that the research results will be a valuable reference for sheep breeding, veterinary orthopedics, and regenerative medicine applications. Additionally, the results are expected to guide future skeletal system research, contributing significantly to productivity and animal health in sheep farming.

2. MATERIALS AND METHODS

In this study, fetuses obtained from clinically healthy, pregnant sheep slaughtered in specialized slaughterhouses in Siirt province were utilized.

Fig. 1. Lateral view of a 70-day-old sheep fetus illustrating the anatomical positioning and morphological appearance of the scapula during the fetal development period

Fetuses were carefully extracted from the collected uteri under controlled conditions, taking particular care to minimize contamination from amniotic fluids and other potential contaminants. Following extraction, fetuses were immediately transferred under sterile and appropriate conditions to the laboratory for further processing and detailed examination. It is important to note that twin pregnancies were not included in this study.

Upon arrival at the laboratory, fetuses underwent careful cleaning to remove residual amniotic fluids and other potential contaminants. They were then promptly fixed and meticulously preserved to maintain structural integrity and minimize any post-mortem morphological changes that could affect morphometric accuracy. Gestational age determination was achieved through precise crown-rump length (CRL) measurements, calculated using the established formula $X = (Y + 17) \times 2.1$, where X represents gestational age in days and Y represents the CRL length in centimeters (Noakes, Parkinson & Gary, 2001; Işbilir & Güzel, 2024; Güzel & Işbilir, 2024).

Subsequently, fetuses were categorized into the following groups based on their gestational ages: 50–60 days (n=2), 60–70 days (n=6), 70–80 days (n=2), 80–90 days (n=1), 90–100 days (n=1), 100–110 days (n=2), 110–120 days (n=2), and 120–130 days (n=2). Scapula samples were precisely dissected and carefully separated from surrounding soft tissues under magnification to ensure accurate and consistent anatomical evaluation. (Fig. 1, Fig. 2).

Measurement points were determined by taking the study of Sasan et al. (2018) as a guide. Measurement parameters are shown in Figure 2. The measurements are as follows:

1. DL: Diagonal Length: Coracoid process to caudal angle length
2. SW-d: Dorsal Scapular Width
3. SW-m: Medial Scapular Width
4. SW-v: Ventral Scapular Width
5. SSL: Scapular Spine Length
6. SCW: Scapular Cartilage Width
7. SCL: Scapular Cartilage Length
8. FSSW: Fossa Supraspinata Width
9. FISW: Fossa Infraspinata Width
10. FSW: Fossa Subscapularis Width

Detailed morphometric analysis was performed utilizing ImageJ software (National Institutes of Health, Bethesda, MD, USA), providing reliable and precise measurements. Data from detailed morphometric assessments were evaluated to identify clear developmental trends and

correlations between specific anatomical measurements and fetal gestational stages.

3. RESULTS

The findings revealed a marked, progressive, significant increase in scapular dimensions associated with advancing fetal age.

Table 1. Descriptive statistical values for morphometric measurements of the fetal scapula in sheep (cm).

	Trimester	n	Mean	SE	SD	Minimum	Maximum
DL	2	12	1.51	0.18	0.65	0.42	2.55
	3	5	4.57	0.29	0.66	3.7	5.36
SW-d	2	12	1.01	0.14	0.48	0.18	1.90
	3	5	2.90	0.16	0.37	2.44	3.36
SW-m	2	12	0.66	0.10	0.34	0.10	1.31
	3	5	1.83	0.09	0.21	1.60	2.10
SW-v	2	12	0.31	0.05	0.18	0.05	0.65
	3	5	0.87	0.08	0.17	0.71	1.12
SSL	2	12	1.26	0.19	0.64	0.28	2.34
	3	5	3.51	0.18	0.40	3.01	3.88
SCW	2	12	1.20	0.19	0.66	0.24	2.52
	3	5	4.40	0.07	0.17	4.22	4.67
SCL	2	12	0.50	0.07	0.23	0.14	0.89
	3	5	1.71	0.18	0.39	1.10	2.07
FSSW	2	12	0.23	0.03	0.11	0.05	0.47
	3	5	0.72	0.07	0.15	0.58	0.97
FISW	2	12	0.62	0.09	0.32	0.09	1.19
	3	5	1.79	0.10	0.22	1.46	1.98
FSW	2	12	0.41	0.66	0.23	0.05	0.87
	3	5	1.64	0.15	0.34	1.37	2.19

DL: Diagonal length (cm), SW-d: Dorsal scapular width (cm), SW-m: Medial scapular width (cm), SW-v: Ventral scapular width (cm), SSL: Spina scapula length (cm), SCW: Scapular cartilage width (cm), SCL: Scapular cartilage length (cm), FSSW: Fossa supraspinata width (cm), FISW: Fossa infraspinata width (cm), FSW: Fossa subscapularis width (cm)

Descriptive statistical data showing morphometric measurements of fetal sheep scapula at different gestational periods were presented in Table 1.

According to the study results, the diagonal length (DL) increased significantly from an average of 1.51 cm in the second trimester (range: 0.42-2.55 cm) to an averag e of 4.57 cm in the third trimester (range: 3.70-5.36 cm). As expected, in addition to morphometric parameters, cartilage scapula width and length parameters were also found to be higher in the last period of pregnancy compared to the second period.

Fig. 2. Morphometric measurements performed on the fetal sheep scapula. Measurements were conducted using anatomical landmarks to ensure accuracy and reproducibility. A: Lateral view of the scapula in a 92-day-old fetus, B: Costal (medial) view of the scapula in a 107-day-old fetus, C: Lateral view of the scapula in a 62-day-old fetus, D: Lateral view of the scapula in a 68-day-old fetus

4. DISCUSSION

The morphometric data from this study demonstrated a progressive and significant growth of the fetal sheep scapula with advancing gestational age. All measured parameters – including overall scapular length, spine length, and the widths of the supra- and infraspinous fossae – increased markedly from the second to the third trimester. These findings indicate that the second half of gestation is a critical period of rapid scapular development, consistent with general principles of fetal osteogenesis in sheep. Previous studies have demonstrated that major ossification processes and growth spurts of appendicular bones in sheep occur particularly during the second and third trimesters of pregnancy. According to Flinn et al. (2022), who studied fetal ossification patterns in domestic sheep (Ovis aries), ossification in the hind limb bones begins approximately on day 45 of gestation, with significant growth occurring in subsequent stages. Furthermore, radiographic studies report marked changes in skeletal mineralization, particularly during the second and third trimesters of gestation, indicating rapid mineralization of bony structures during this period (Güzel & Işbilir, 2024). This aligns with our observations of accelerated scapular development in the late fetal stages. This substantial prenatal growth of the scapula is biologically necessary, as the shoulder girdle must be sufficiently developed by birth to support the neonate's mobility. Sheep are a precocial species, and lambs are typically able to stand and ambulate within hours of birth; accordingly, their musculoskeletal system (including the scapula) must reach a high degree of maturity before parturition (Ahmed, 2008). The pronounced increases in scapular dimensions we observed can therefore be interpreted as the fetus's preparation for postnatal life, ensuring that the shoulder blade will have the size and strength to contribute to weight-bearing and locomotion immediately after birth.

The timing of scapular ossification observed in prior studies provides a useful framework for interpreting our morphometric results. It is well documented that the sheep scapula begins ossifying relatively early in gestation: a primary ossification center in the scapular body appears at around day 45 of gestation (Succu et al., 2023). In line with our findings, previous radiographic studies by Wenham (1981) have also documented early skeletal development in fetal sheep, noting particularly significant mineralization events during gestation. Wenham observed notable changes in skeletal mineralization occurring between 34 and 41 days of gestation, during which critical components of the axial and appendicular skeleton—including the scapula—became radiographically evident. This aligns closely with our findings of accelerated scapular morphometric growth during mid-to-late gestation, supporting the assertion that ossification processes and bone development in sheep occur extensively and rapidly during the second and third trimesters (Wenham, 1981). Similar observations regarding scapular morphometric development have been reported in other sheep breeds. For instance, Isaenkov et al. (2019) conducted morphometric analyses on Romanov sheep scapulae throughout ontogenesis, demonstrating substantial increases in scapular mass, length, and width during prenatal development and significant morphological differences between sexes. The study particularly emphasized that scapular length and width exhibit

synchronized growth patterns corresponding to increased scapular mass, supporting the notion that critical structural maturation of scapular bones occurs progressively throughout fetal life and continues postnatally (Isaenkov et al., 2019). Furthermore, Harris (1937) conducted a comprehensive radiographic and histological investigation of fetal skeletal development in sheep, highlighting critical periods of ossification. Harris documented the precise sequence of ossification centers' appearance, noting significant morphological and developmental similarities as well as differences between sheep and other mammalian species, including humans. The scapula, among other bones, was observed to develop rapidly, with an identifiable ossification center appearing early in gestation (around 45 days), emphasizing its accelerated maturation relative to humans. This aligns closely with our findings, further validating the timing and morphological changes observed in scapular development during fetal growth in sheep (Harris, 1937). Beyond sheep, similar developmental patterns are reported in other domestic ruminants, underscoring the generality of our observations. In goat fetuses (which have a gestation length comparable to sheep), primary ossification centers in the scapula also become evident around 7–8 weeks into gestation, and all scapular measurements then increase linearly with fetal age up to term (Parmar et al., 2024).

5. CONCLUSION

In conclusion, this study provides a comprehensive characterization of the morphometric and morphological development of the fetal sheep scapula during mid to late gestation. We found that scapular dimensions increase in a consistent, predictable manner with advancing fetal age, with significant growth spurts occurring in key parameters such as overall length, spine length, and the widths of important fossae. These results delineate the timeline by which a relatively small, predominantly cartilaginous early fetal scapula transforms into a larger, mostly ossified structure by the third trimester, ready to meet the functional demands of neonatal life. The main findings highlight that the sheep scapula undergoes rapid and coordinated growth, ensuring that by the time of birth the bone has achieved the form necessary for effective muscle attachment and limb support. Such knowledge is highly relevant both clinically and academically. Clinically, our data will serve as reference values for normal fetal development, aiding veterinarians in estimating fetal age and in the early detection of developmental abnormalities or growth retardation. Academically, the findings will enrich the understanding of veterinary developmental anatomy and will provide a basis for further research into skeletal growth and its regulation. Ultimately, by elucidating how the fetal scapula grows and matures, this work will add an important piece to the larger puzzle of prenatal musculoskeletal development and will lay the groundwork for future studies and applications in veterinary medicine and animal science.

Ethical Statement

With the ethics committee report numbered 2025/02/06, the Siirt University Experimental Animals Application and Research Center approved the procedures used in this investigation.

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