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# Investigation of Metapodium and Acropodium Bones in Siirt-Colored Mohair Goat (*Capra hircus*) by 3D Modeling

**Fatma İŞBİLİR[1,a,*] , Barış Can GÜZEL[1,b]**

[1]Siirt University, Department of Anatomy, Faculty of Veterinary Medicine, Siirt, Turkey.

[a]ORCİD: 0000-0002-6110-1302

[b]ORCID: 0000-0002-2504-120X

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***Correspondence:** Fatma İŞBİLİR
Siirt University, Department of Anatomy, Faculty of Veterinary Medicine, Siirt, Turkey.
e-mail: fatmaisbilir42@gmail.com

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**Abstract:** Studies on Artiodactyla species benefit from the use of metapodial bones. Being one of the bones that completed its development early and being well preserved because it is not affected by environmental conditions, it can be unearthed as a single piece in archaeological excavations. In recent years, the disadvantages of 2D images have contributed to developing 3D modeling methods in medicine. Adult (1-3 years old), 10 male and 10 female Siirt-colored Mohair goat metacarpus and forelimb digit bones (phalanx proximalis, phalanx media and phalanx distalis) were used in our study. Bones were scanned with a computed tomography device. The resulting images were saved in DICOM format and 3D models were created using a special software. 14 osteometric measurements were taken from the metacarpus and 12 from the digit bones. The results were evaluated statistically. As a result of the statistical evaluation, in the metacarpus; Smallest Breadth of diaphysis (Sd), Breadth of distal (Bd), Medio-lateral width of condylus medialis width of condylus medialis (WCM), Depth of proximal (Dp), Antero-posterior diameter of external trochlea of condylus medialis (Dem) and Antero-posterior diameter of internal trochlea of condylus medialis (Dim) parameters were found to be statistically significant between males and females ($P<0.01$). For phalanx media, GLpe and Bp measurement parameters were statistically significant between genders ($P<0.05$). The data obtained from the study will contribute to anatomy education, the classification of bones obtained in zoo-archaeological excavations, and the determined anatomical features that will contribute to surgical approaches.

***Keywords:*** *Acropodium, Metapodium, Siirt-colored Mohair goat (Capra hircus), 3D modelling.*

## Siirt Renkli Tiftik Keçisinde (*Capra hircus*) Metapodium ve Acropodium Kemiklerinin 3D Modelleme ile İncelenmesi

**Özet:** Artiodactyla türlerine ilişkin çalışmalarda metapodial kemikler önemlidir. Gelişimini erken tamamlayan kemiklerden biri olması ve çevre koşullarından etkilenmemesi nedeniyle iyi korunmuş olması, arkeolojik kazılarda tek parça olarak ortaya çıkarılmasına olanak sağlamaktadır. Son yıllarda 2 boyutlu görüntülerin dezavantajları tıpta 3 boyutlu modelleme yöntemlerinin gelişmesine katkı sağlamıştır. Çalışmamızda yetişkin (1-3 yaş), 10 erkek ve 10 dişi Siirt renkli tiftik keçisinin metakarpusu ve ön ayak parmak kemikleri (phalanx proximalis, falanx media ve falanx distalis) kullanıldı. Kemikler bilgisayarlı tomografi cihazıyla tarandı. Ortaya çıkan görüntüler DICOM formatında kaydedildi ve özel bir yazılım kullanılarak 3 boyutlu modeller oluşturuldu. Metacarpus'tan 14, parmak kemiklerinden 12 osteometrik ölçüm alındı. Sonuçlar istatistiksel olarak değerlendirildi. İstatistiksel değerlendirme sonucunda metakarpusta; En küçük diyafiz genişliği (Sd), distal genişliği (Bd), condylus medialis medialis medialis genişliği (WCM), proksimal derinliği (Dp), condylus medialis eksternal troklea ön-arka çapı (Dem) ve Condylus medialis internal troklea ön-arka çapı (Dim) parametreleri dişiler ve erkekler arasında istatistiksel olarak anlamlı bulundu ($P<0.01$). Falanks ortamı için GLpe ve Bp ölçüm parametreleri cinsiyetler arasında istatistiksel olarak anlamlıydı ($P<0.05$). Çalışma sonucunda elde edilen verilerin anatomi eğitimine katkı sağlayacağı, hayvanat bahçesi-arkeolojik kazılarda elde edilen kemiklerin sınıflandırılması ve belirlenen anatomik özelliklerin cerrahi yaklaşımlara katkı sağlayacağı düşünülmektedir.

***Anahtar Kelimeler:*** *Akropodyum, Metapodyum, Siirt renkli tiftik keçisi (Capra hircus), 3 boyutlu modelleme.*

## Introduction

Bone remains obtained during archaeological excavations can provide information about the conditions of the day. The importance of these bones in terms of animal morphology is indisputable. Since metapodial bones are among the bones that finish developing early in life, they are significant in studies on Artiodactyla species. In addition, since it is well preserved and not affected by environmental conditions, it was generally revealed as a single piece during archaeological excavations (Bartosiewicz, 1985; Berteaux and Guintard 1995). For this reason, metapodium bones were examined in many excavations (Ince et al., 2018; Pazvant et al., 2015). The study of metapodial bones contributes to elucidating the history of sheep (Lamelland, 2002; Onar et al., 2008) and goat (Ince et al., 2018; Zeder 2001) domestication and estimating body conditions at that time (Guintard and Lallemand 2003; Lamelland, 2002). A study stating that the metapodium of the goat is shorter and broader than that of the sheep (Boessneck, 1969) supports the information that metapodial bones were used to distinguish the bones of sheep and goats in the Neolithic period (Rowley-Conwy, 1998).

Ruminants possess two fully developed digits, with three phalanges on each toe. Phalanx proximalis, phalanx medium, and phalanx distalis are the names of the three bones that comprise the digits (Bahadır and Yıldız 2016; Konig and Liebich 2020). The phalanx proximalis is the longest of them (Al-Sharoot, 2013). The length of the phalanx media is nearly half that of the phalanx proximalis. The nail bone, or phalanx distalis, is shaped differently from the bones of the other two fingers. In terms of surgery, it is crucial to understand the specific architecture of the metapodium and acropodium areas for the bone and the flexor and extensor muscles related to it (Demircioglu et al., 2021).

Using medical imaging equipment, two-dimensional (2D) pictures of significant bodily structures can be acquired. Various software can be used to study, measure, or divide images of the necessary anatomical structure (Demircioglu and Gezer 2020; Freitas et al., 2011; Ozkadif and Eken 2015; Sergovich et al., 2010; Yılmaz and Demircioglu 2021). The significance of 3D investigations is growing as a result of the drawbacks of 2D traditional imaging techniques as reduction, superposition, and magnification (Allowen et al., 2016; Aydogdu et al., 2021; Mirjana et al., 2014). Recently, one of the most popular approaches in medicine has been the use of three-dimensional modeling (D'Urso et al., 1999). Clinical instances, pathological cases, forensic medicine cases, and anthropological research all use reconstructive images (Verhoff et al., 2007). Furthermore, the utilization of computed tomography images in 3D modeling has gained popularity as a teaching tool for anatomy (Kong et al., 2016).

There are studies on the morphology and morphometry of metapodium bones from various sheep breeds, including Shetland sheep (Davis, 1996), Bardhoka (Gundemir et al., 2020), Hemsin (Gurbuz et al., 2018), Tuj and Morkaraman (Demiraslan et al., 2015), and Hamdani (Guzel et al., 2022). Pazvant et al. (2015) and Onar et al. (2008) also osteometrically examined sheep and goat metapodiums obtained from excavations in Istanbul and the Eastern Anatolia Region. Furthermore, investigations using 3D modeling were done on gazelles' acropodium bones (Demircioglu et al., 2021).

It is known that the majority of colored Mohair goats have been bred in Siirt, Batman and Sırnak provinces for a long time in Turkey (Gunes and Evrim 1993; Ilgaz and Sevinc 1982). These Mohair goats are crucial in weaving bags, vests, gloves, caps, socks and various ornaments offered to the market for touristic purposes, especially in weaving the famous Siirt blanket in the Siirt region. Siirt-colored Mohair goats are small in build. The Mohair covering them is thin, curved and shiny, black, white, gray, light red, brown, buff and yellow. The whole body is covered with Mohair except for the face and legs. Goats have a small, graceful head, bright and lively eyes. Although weak in females, the state of being horned is a general racial trait. The horns mostly follow a vertical course first and then laterally (Yerturk and Odabasıoglu 2007).

The aim of the study is to determine the morphometric characteristics of the metacarpus and forelimb digit bones of Siirt-colored Mohair goats by 3D modeling method, taking into account the gender difference. It is foreseen that the data obtained as a result of the study, the differences in terms of sex in Siirt-colored Mohair goats, and the measurements taken from the anatomically determined points will be used clinically and taxonomically.

## Material and Methods

Adult (1-3 years old), 10 male and 10 female Siirt-colored Mohair goat metacarpus and forelimb digit bones (phalanx proximalis, phalanx media and phalanx distalis) were used in our study. The bones were obtained from animals slaughtered in the slaughterhouse of Siirt province. Following the maceration procedure, 12 measurements from the digit bones and 14 measurements from the metacarpus were obtained. Measurement points were determined with guidance from Guintard (1998), Guintard and Lallemand (2003) and von Den Driesch (1976). Measuring points are shown in Figures 1,2,3 and 4. The nomenclature was made in accordance with Nomina Anatomica Veterineria (2017). For three-dimensional measurements, a computerized tomography device in the department of radiology at Siirt University, Faculty of Medicine was used. A 64-detector MDCT scanner was used to scan the bones at 80 kV, 200 MA, 639 mGY, and 0.625 mm slice thickness. CT scans were recorded in the DICOM format according to the scan dose and protocol. Reconstructions were created with the help of the 3d slicer (5.02) software program. A segmentation technique was used on the CT images taken. The following osteometric measurements were made on the created 3D models. Statistical evaluation was made with the SPSS 22.0 program from the measurement results. The data from males and females were compared using an independent sample t-test.

***Measurements points***

***Metacarpus (Figure 1)***

GL: The greatest Length

Bp: The proximal breadth

Be: The metaphysis's maximum depth

De: Maximum metaphysis width

Sd: Smallest Diaphysis Breadth

Dp: Proximal Depth

BD: Distal breadth

Dd: Distal portion's depth

DIL: Antero-posterior diameter of internal trochlea of condylus lateralis

DEL: Antero-posterior diameter of external trochlea of condylus lateralis

DIM: Antero-posterior diameter of internal trochlea of condylus medialis

DEM: Antero-posterior diameter of external trochlea of condylus medialis

WCL: Medio-lateral width of condylus lateralis

WCM: Medio-lateral width of condylus medialis width of condylus medialis

***Phalanx Proximalis (Figure 2)***

A1. GLpe: Greatest abaxial half length (GLpe)

A2. Bp: The proximal end's breadth (Bp)

A3. SD: Diaphysis's smallest width (SD)

A4. Bd: The distal end's breadth (Bd)

***Phalanx Media (Figure 3)***

A5. GLpe: Greatest abaxial half length

A6. Bp: The proximal end's breadth

A7. SD: Diaphysis's smallest width

A8. Bd: The distal end's breadth

A9. GL: Greatest length (in dorsal direction)

***Phalanx Distalis (Figure 4)***

A10. DLS: The sole's longest diagonal length

A11. Ld: The dorsal surface's length

A12. MBS: Middle width of the sole

With the ethics committee report numbered 2023/03/24, the Siirt University Experimental Animals Application and Research Center approved the procedures used in our investigation.

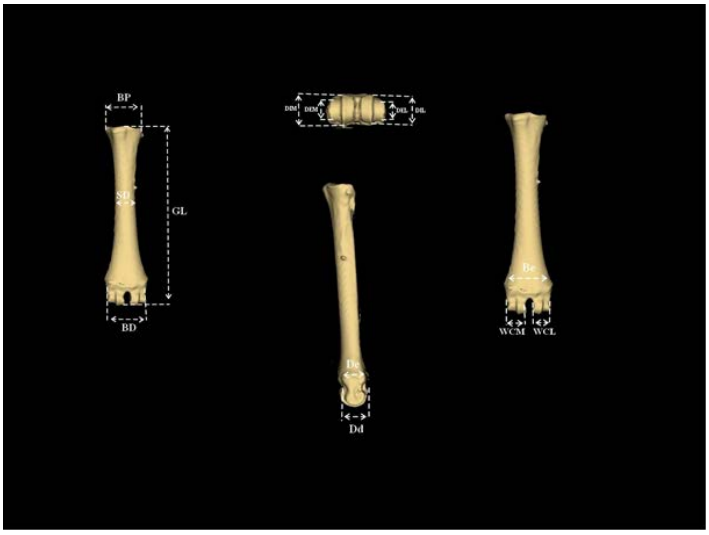


**Figure 1:** Osteometric measuring sites on the Siirt-colored Mohair goat's metacarpus bone.

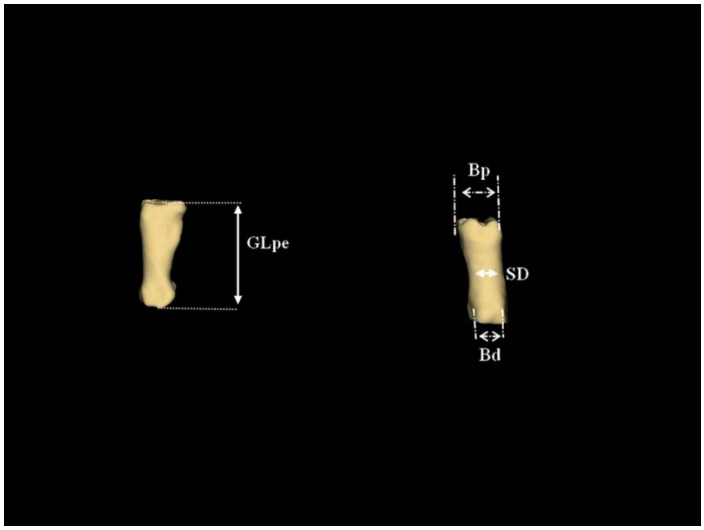


**Figure 2:** Osteometric measuring locations of the Siirt-colored Mohair goat's phalanx proximalis bone.

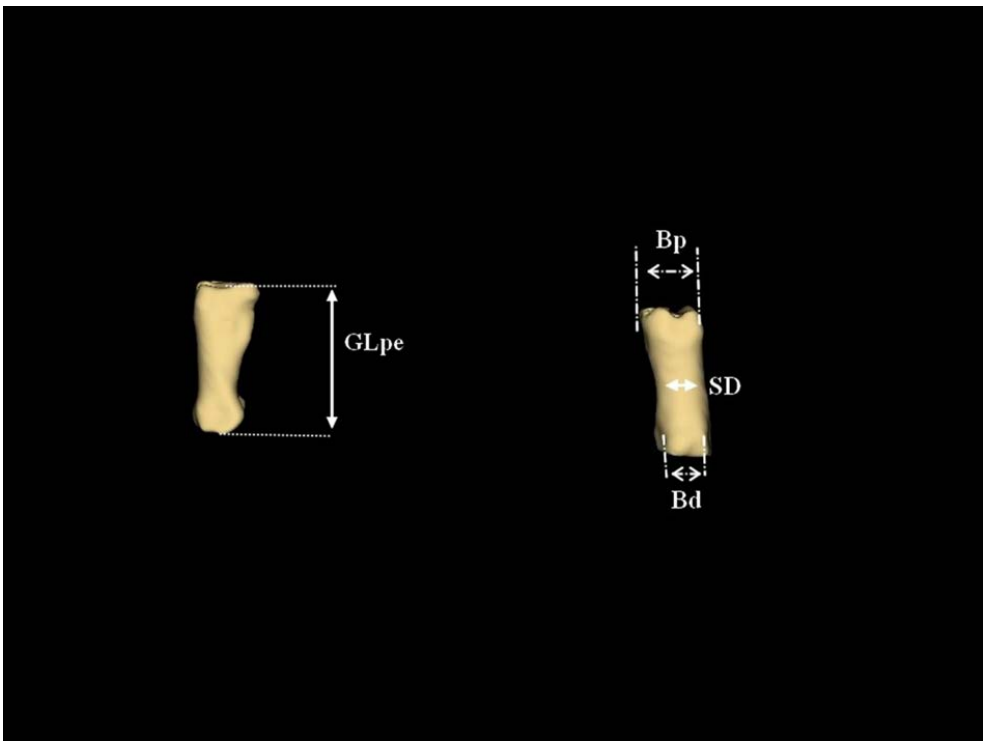


**Figure 3:** Osteometric measuring locations of the Siirt-colored Mohair goat's phalanx media bone.

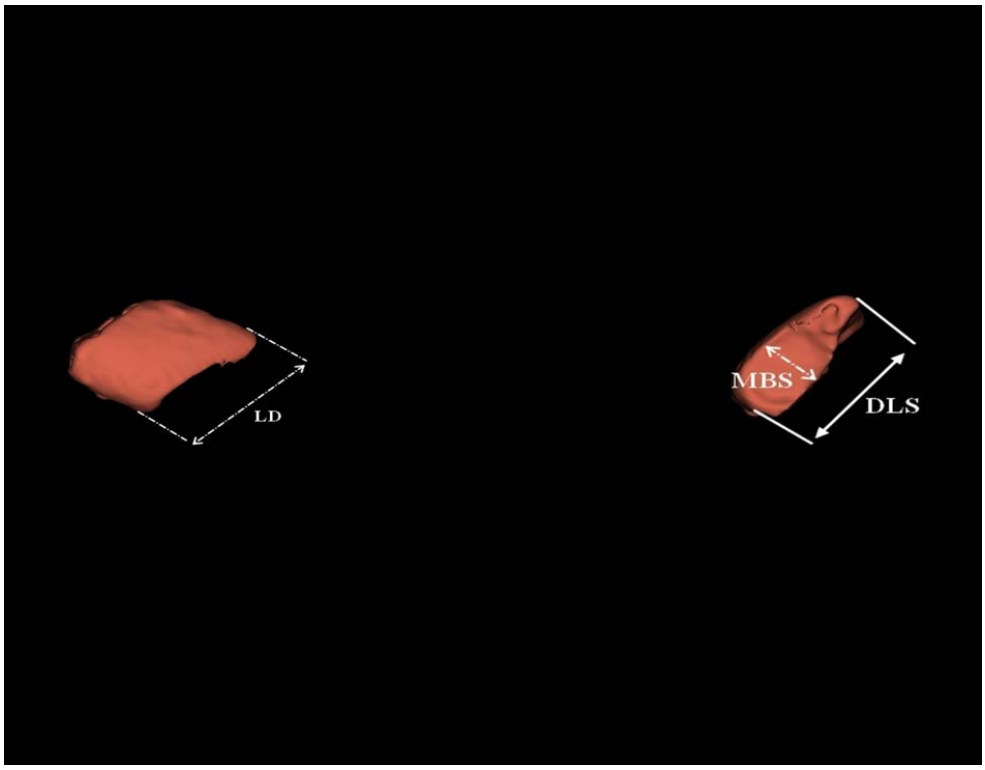


**Figure 4:** Osteometric measuring locations of the Siirt-colored Mohair goat's phalanx distalis bone.

## Results

Tables 1 and 2 present the measurement results of the Siirt-colored Mohair goat's metacarpus and forelimb digit bones (phalanx proximalis, media, and distalis) from our investigation. Males were shown to have a greater metacarpus total length (GL) than females. The parameters measuring the Smallest Breadth of diaphysis (SD), Breadth of distal (Bd), Medio-lateral width of condylus medialis width of condylus medialis (WCM), Depth of proximal (Dp), Antero-posterior diameter of external trochlea of condylus medialis (DEM) and Antero-posterior diameter of internal trochlea of condylus medialis (DIM) were found to be statistically significant ($P<0.01$) when comparing males and females.

**Table 1.** Osteometric measurement results of metacarpus bones in Siirt-colored Mohair goats.

| | Group | N | Mean | Std. Error of Mean | P |
|---|---|---|---|---|---|
| **GL** | Male | 10 | 126.82 | 1.93 | 0.995 |
| | Female | 10 | 121.96 | 2.43 | |
| **Sd** | Male | 10 | 26.89 | 2.13 | 0.001 |
| | Female | 10 | 20.64 | 0.58 | |
| **Bp** | Male | 10 | 24.08 | 1.10 | 0.821 |
| | Female | 10 | 18.80 | 1.94 | |
| **BD** | Male | 10 | 21.04 | 2.45 | 0.002 |
| | Female | 10 | 13.85 | 0.25 | |
| **Be** | Male | 10 | 26.06 | 0.75 | 0.046 |
| | Female | 10 | 27.87 | 0.47 | |
| **WCM** | Male | 10 | 28.97 | 2.62 | 0.003 |
| | Female | 10 | 22.20 | 0.47 | |
| **WCL** | Male | 10 | 12.04 | 0.33 | 0.014 |
| | Female | 10 | 12.16 | 0.19 | |
| **Dp** | Male | 10 | 15.49 | 1.18 | 0.005 |
| | Female | 10 | 12.59 | 0.27 | |
| **DEM** | Male | 10 | 12.00 | 0.19 | 0.006 |
| | Female | 10 | 11.90 | 0.45 | |
| **DIM** | Male | 10 | 14.66 | 0.88 | 0.001 |
| | Female | 10 | 12.21 | 0.38 | |
| **DEL** | Male | 10 | 12.02 | 0.39 | 0.416 |
| | Female | 10 | 11.41 | 0.36 | |
| **DIL** | Male | 10 | 16.85 | 0.31 | 0.412 |
| | Female | 10 | 16.76 | 0.46 | |
| **Dd** | Male | 10 | 16.93 | 1.10 | 0.015 |
| | Female | 10 | 14.21 | 0.38 | |
| **De** | Male | 10 | 17.58 | 0.39 | 0.940 |
| | Female | 10 | 17.08 | 0.50 | |

**Table 2.** Osteometric measurement results of digit bones (phalanx proximalis, phalanx media and phalanx distalis) in Siirt-colored Mohair goats.

| | Group | N | Mean | Std. Error of Mean | P |
|---|---|---|---|---|---|
| **A1** | Male | 10 | 38.04 | 0.37 | 0.407 |
| | Female | 10 | 35.18 | 0.27 | |
| **A2** | Male | 10 | 17.31 | 0.42 | 0.609 |
| | Female | 10 | 15.57 | 0.26 | |
| **A3** | Male | 10 | 15.65 | 0.19 | 0.851 |
| | Female | 10 | 14.11 | 0.24 | |
| **A4** | Male | 10 | 16.12 | 0.19 | 0.009 |
| | Female | 10 | 14.33 | 0.11 | |
| **A5** | Male | 10 | 21.70 | 0.27 | 0.013 |
| | Female | 10 | 18.75 | 0.18 | |
| **A6** | Male | 10 | 14.37 | 0.13 | 0.024 |
| | Female | 10 | 13.17 | 0.24 | |
| **A7** | Male | 10 | 12.78 | 0.34 | 0.267 |
| | Female | 10 | 11.00 | 0.24 | |
| **A8** | Male | 10 | 20.55 | 0.24 | 0.824 |
| | Female | 10 | 19.19 | 0.19 | |
| **A9** | Male | 10 | 11.99 | 0.20 | 0.616 |
| | Female | 10 | 11.49 | 0.24 | |
| **A10** | Male | 10 | 62.15 | 0.36 | 0.534 |
| | Female | 10 | 58.31 | 0.41 | |
| **A11** | Male | 10 | 51.60 | 0.30 | 0.460 |
| | Female | 10 | 48.99 | 0.25 | |
| **A12** | Male | 10 | 38.55 | 0.34 | 0.556 |
| | Female | 10 | 34.58 | 0.23 | |

There was a significant difference between the genders in the maximum depth of the metaphysis (Be) and the depth of the distal (Dd) measuring sites (P<0.05). When the results of measurements of the phalanxes were examined, it was seen that the A1 and A5 measurement parameters were larger in males than in females. Considering the A4 measurement

point parameter, it was determined to be statistically significant (P<0.01). A5 and A6 measurement parameters were found to be statistically significant (P<0.05).

## Discussion and Conclusion

In connection with the importance of mohair, although some selection studies have been carried out, especially in Ankara Mohair goats, conscious selection and breeding studies have not been carried out in colored Mohair goats (Yerturk and Odabasıoglu 2007). Morphological and morphometric characteristics of Siirt-colored Mohair goats are uncertain due to a lack of studies. While the Siirt-colored Mohair goat constitutes the majority of the colored Mohair goats raised in Turkey, it has great economic importance. Metapodium and acropodium bones in different species and races were evaluated osteometrically. However, such a study was not found in the Siirt-colored Mohair goat.

The aim of the study was to determine the morphometric characteristics of the metacarpus and forelimb digit bones of the Siirt-colored Mohair goat by performing osteometric analyses with 3D modeling and to reveal the differences between the sexes. The results obtained will help in the taxonomy of the bones obtained as a result of zoo-archeologic excavations.

The GL values in sheep and goat metacarpus unearthed in the Yenikapı metro and Marmaray excavations were 124.91±11.04mm and 115.52±9.44mm, respectively (Pazvant et al., 2015), 122.72±7.80mm in adult sheep, and 100.96±9.70mm in adult goats (Onar et al., 2008). In the study conducted in the Bardhoka sheep breed, this parameter was reported as 148.48±8.05mm in males and 139.19±6.61mm in females (Gundemir et al., 2020). In our study, the GL value was determined as 126.82±1.93mm in male goats and 121.96±2.43mm in females, and this parameter was found to be higher in male animals than in female animals.

In our study, the Sd parameter was determined as 26.89±2.13mm in male goats and 20.64±0.58mm in female goats, similar to Morkaraman sheep (Demiraslan et al., 2015), statistical differences were observed between male and female goats (P<0.01). The same parameter was reported as 13.29±0.79mm in males and 13.25±1.14mm in females in Hamdani sheep (Guzel et al., 2022). Gurbuz et al. (2018) reported this value as 15.10±0.34mm in Hemsin rams, while it was reported as 14.75±0.79mm in females and 13.64±0.50mm in males in Morkaraman sheep (Demiraslan et al., 2015).

Demiraslan et al. (2015) reported the BD value as 28.51±1.13mm, 27.89±1.37mm in Tuj sheep breeds in males and females, and 29.42±0.60mm and 27.47±3.55mm in Morkaraman sheep in their study in Tuj and Morkaraman sheep. While the exact value was reported as 27.22±0.86mm in females and 30.49±1.19mm in males in the Bardhoka sheep breed (Gundemir et al., 2020), it was determined as 25.12±1.04mm and 26.03±1.26mm in adult sheep and goats, respectively (Onar et al., 2008). In our study, this value was determined as 21.04±2.45mm in male goats and 13.85±0.25mm in females, and a statistically significant difference was observed between the sexes (P<0.01).

The WCM value was 12.66±1.21mm and 13.44±0.97mm in sheep and goat metacarpus unearthed in Yenikapı metro and Marmaray excavations (Pazvant et al., 2015). This parameter was determined as 12.06±0.83mm in males and 11.69±1.33mm in females in the Hamdani sheep breed (Guzel et al., 2022). In the present study, a significant difference was observed between female and male goats in terms of WCM value (P<0.01). While Onar et al. (2008) reported the Dp value as 16.75±0.87mm and 16.03±1.22mm in adult sheep and goats, respectively, this parameter was determined by Gundemir et al. (2020) as 19.5±1.23mm in females and 21.1±1.46mm in males in Bardhoka sheep. In our study, the Dp value was measured as 15.49±1.18mm in male goats and 12.59±0.27mm in female goats.

In the presented study, another parameter for which statistical difference was determined between the genders is the DEM parameter (P<0.01). While this parameter was reported as 13.50±0.36mm in Morkaraman rams and 12.99±0.57mm in sheep, in the same study it was determined as 13.139±0.73mm in Tuj rams and 13.14±0.55mm in sheep (Demiraslan et al., 2015). It has been reported to be 12.33±0.74mm in Hemsin rams (Gurbuz et al., 2018).

DIM parameter Pazvant et al. (2015) determined it to be 14.24±1.29mm and 14.75±1.40mm in sheep and goats, respectively, while the same parameter was reported as 15.40±2.42mm in Hamdani rams and 14.33±1.42mm in sheep (Guzel et al., 2022). In our study, the DIM parameter was determined as 14.66±0.88mm in male goats and 12.21±0.38mm in female goats. In addition, statistically significant differences were observed between the genders (P<0.01).

Be and Dd parameters, respectively, were reported as 27.09±0.73mm and 11.21±0.26mm in Hemshin rams (Gurbuz et al., 2018), 26.21±4.30mm and 12.30±2.23mm in Hamdani rams and 25.82±2.40mm and 11.27±1.41mm in Hamdani ewes (Guzel et al., 2022). Demiraslan et al. (2015) reported these two values as 31.36±1.14mm and 18.47±0.67mm in Morkaraman rams, 29.78±1.26mm and 16.54±1.52mm in sheep, respectively. In the same study, the values were reported as 31.02±1.51mm and 17.79±0.74mm in Tuj rams, 28.39±3.31mm and 17.37±3.31mm in sheep, respectively. In our study, as in Morkaraman sheep, a significant difference was determined between the sexes regarding Be and Dd parameters (P<0.05).

According to a study by Gundemir et al. (2020), the forelimbs had a greater GLpe measuring parameter of the phalanx proximalis than the hindlimbs. In black Bengal goats, Siddiqui et al. (2008) observed this value to be 1.88±0.03cm in the phalanx media of the forelimbs, and in gazelles, Demircioglu et al. (2021) reported it to be 1.95±5.59cm. According to sexual dimorphism, the GLpe parameter in the study on gazelles was shown to be significant for all extremities, with the exception of the left hind extremity phalanx media (Demircioglu et al., 2021). In our study, it was determined that the GLpe parameter in phalanx proximalis was higher in male goats than in female goats. In addition, it

was observed that the GLpe parameter had a significant difference between genders for phalanx media (P<0.05).

According to Nourinezhad et al. (2012), there was a statistically significant variation in the breadth of the distal end (Bd) of the proximal phalanx in buffaloes. Furthermore, Demircioglu et al. (2021) found that there was a statistically significant difference in the Bd values of the left forefoot inner, right forefoot inner, right forefoot outer, and right hindfoot outer bones between male and female gazelles. Similar to this, our study revealed a significant difference (P<0.01) in the Bd value for the phalanx proximalis between the genders. In addition, in our study, it was determined that the Bd value for the phalanx proximalis bone was higher in male goats than in female goats.

The GL, SD, and Bp values of the phalanx media were shown to be statistically significant in investigations on domestic cattle and water buffaloes (Gundemir et al., 2020; Nourinezhad et al., 2012). According to Bp, SD measures, and index values, there was no statistically significant sexual dimorphism seen in gazelles (Demircioglu et al., 2021). However, in our study, sexual dimorphism was determined in the phalanx media bone in terms of the Bp parameter (P<0.05).

As a result of the study, it was seen that certain values of metacarpus and forelimb digit bones in Siirt-colored Mohair goats showed statistically significant differences according to gender. For this reason, due to the compact structure of metapodium and acropodium bones, it is clear that they will make a great contribution to taxonomy if they are obtained in zoo-archaeological excavations. This study, in which the morphometric characteristics of the metacarpus and digit bones of the Siirt-colored Mohair goat, which has different phenotypic properties, are determined by 3D modeling, will help to classify the bones obtained in the excavations. In addition, we think that it will be important to know the morphometric structure of the region in surgical approaches to the metapodial and digit bones.

## Conflict of Interest

The authors stated that they did not have anyreal, potential or perceived conflict of interest.

## Ethical Approval

The procedures applied in our study were approved by the Siirt University Experimental Animals Application and Research Center with the ethics committee report numbered 2023/03/24.

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## Similarity Rate

We declare that the similarity rate of the article is 14% as stated in the report uploaded to the system.

## Author Contributions

Motivation / Concept: Fİ, BCG
Design: Fİ
Control/Audit: BCG
Data Collection and/or Processing: Fİ
Analysis and/or Interpretation: BCG
Literature Review: Fİ
Posted By: Fİ, BCG
Critical Review: Fİ, BCG

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