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Research Article

Investigation of the shape of goat (capra hircus) astragalus via geometric morphometry method

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The present study was presented at the XIIth National/IIIth International Veterinary Anatomy Congress on September 27-29, 2023.

ABSTRACT

The aim of this study is to determine the effect of sex on shape of goat astragalus via geometric morphometry method. A total of 37 astragalus bone samples collected from 16 female and 21 male goats were used as material. Bone samples were cleaned from skin and soft tissue and then macerated by boiling. Astragalus bone samples were photographed from a distance of 20 cm dorsally by focusing on the center of the bone. The photographs were transferred to the computer in JPEG format. Principal Component Analysis, Regression Analysis, Canonical Variate Analysis, and Discriminant Function Analysis were conducted using the Cartesian coordinate values, which were obtained by homologous landmark marking. The first two principal components accounted for 75.967% of the total shape variation. Shape variation was determined in different regions of the astragalus. According to the scatter plot of male and female individuals, male individuals were completely placed within the confidence interval ellipse of female individuals. It was found that allometric effect on the shape of astragalus bone was not statistically significant. As a result of Canonical Variate Analysis, mahalanobis and procrustes distances were detected as 2.9216 ($p<0.0001$) and 0.0645 ($p=0.0035$), respectively. This test indicated two female individuals in the group of males. The proximal of male goat astragalus was wider than that of female goats. The results of the Discriminate Function Analysis revealed that 8 of the female individuals and 7 of the male individuals were incorrectly grouped according to the cross validation scores. Geometric morphometry and the related analyses allowed to examine the differences between the astragalus bone samples of male and female goats. The fact that the astragalus bone of male goats was wider than that of females supported the studies using linear measurements in the literature. Consequently, the result indicating that sex factor had a limited grouping effect on astragalus shape in goats was obtained.

INTRODUCTION

Capra hircus is a species known as domestic goat belonging to the genus Capra of the family Bovidae (Payne and Wilson, 1999). Goats, known as the first domesticated animal species (Zeder and Hesse, 2000), have been in relation with humans since about 10.000 years ago according to the archeological findings. Human beings have reared goats as of ancient times to obtain animal products. The reason for being a common species when compared to other animal species is their easy adaptation to environmental conditions and their resistance to diseases and parasites (Naderi et al., 2008).

Geometric morphometry is the analysis of shape variables including all geometric information in the data (Slice, 2007). This method is based on the quantification of the shape of the material by using two- or three-dimensional coordinates of anatomical landmarks and semi-landmarks (Gonzalez et al., 2009). In geometric morphometry, measurements are taken with three-dimensional digitalization tools or special software (Aytek, 2017). This method directly focuses on shape differences in individuals and/or groups (Özkan, 2022).

Astragalus is the second largest tarsal bone after the calcaneus. It consists of three parts: corpus tali, collum tali, and caput tali (Motagi et al., 2015). The trochlea of the astragalus articulates with the tibia and its plantar and lateral parts articulate with the calcaneus (König and Liebich, 2013).

Especially in forensic deaths and archaeological remains, bones are often found as fragmented and mixed (Figus et al., 2017). For these reasons, biological profiles are created from different bones that can be an alternative to bones such as pelvic and cranial bones, which are important in sex determination (Brzobohat, 2015). It is known that individuals of different sexs have different gait kinetics, postures, and joint angles (Graci et al., 2012). It is thought that these differences may be reflected in the general shape of the astragalus (Sorrentino et al., 2020). There have been studies in the literature in which linear measurements of bones such as astragalus and calcaneus were performed (Davies et al., 2014; Nathena et al., 2017). However, it is known that studies conducted with linear measurements have some limitations (Lee et al., 2015). Geometric morphometry eliminates the limitations of linear measurements (Kranioti et al., 2009) as it provides too much data on shape (Aytek, 2017).

The geometric morphometry method was preferred as it eliminates the limitations of linear measurements and it was aimed to investigate its role in sex determination.

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MATERIALS and METHODS

A total of 37 right astragalus bones from 16 adult (2-3 years old) female goats and 21 adult (2-3 years old) male goats were used in the study. Bone materials were cleaned from skin and soft tissue and then boiled. After boiling, the tissues remaining on the bone were well cleaned.

Geometric Morphometric Analysis

Astragalus bones were photographed from a distance of 20 cm from the dorsal side and focusing on the center of the bone (Canon 600D 18x55 lens, Japan). The photographs were transferred to computer in JPEG format. These images were converted to tps format using TpsUtil (Version 1.79) software (Rohlf, 2019). Cartesian coordinates of homologous LMs (sign element) were determined by marking on the images with TpsDig2 (Version 2.31) software (Rohlf, 2018). Principal Component Analysis (PCA) was performed on the coordinates. MorphoJ (Klingenberg, 2011) software was used to determine the LM levels and directions where shape differences were observed between groups. Regression analysis was performed to determine the allometric effect (Jeanjean et al., 2022). Canonical Variate Analysis (CVA) and Discriminate Function Analysis (DFA) were then performed to analyze the accuracy of classification.

LMs marked on dorsal surface of the astragalus (Figure 1);

1. Most proximal end of lateral proximal condyl
2. Lateral side of the center
3. Most lateral end of distal lateral condyl
4. Most medial end of distal lateral condyl
5. Most concave point between distal lateral and medial condyle
6. Most lateral end of distal medial condyl
7. Most medial end of distal medial condyl
8. Distal start point of the medial eminence
9. Peak point of the medial eminence
10. Proximal start point of the medial eminence
11. Most proximal end of medial proximal condyl
12. The most proximal concave point between the lateral and medial condyle

RESULTS

A total of 20 principal components were calculated in the study. PC1 accounted for 53.891% of the total shape variation. The first 2 principal components accounted for 75.967% of the total shape variation.

Figure 2 shows the shape variation graph obtained from principal component analysis. Accordingly, LM2, LM8, LM9, LM10, and LM11 were determined as the landmarks with the most significant amount of first order variation. Secondarily responsible landmarks were determined as LM1 and LM7. The other landmarks contributed the least to the amount of variation. Therefore, variation was determined in the central lateral edge, medial eminence and medial proximal condyle of the astragalus (Figure 2).

According to the scatter plot of male and female individuals in goats, male individuals were completely placed within the confidence interval ellipse of female individuals (Figure 3).

Size had an allometric effect of 3.0326% on the shape. The allometric effect was not statistically significant in the 10.000 rounds permutation test (P=0.3200).

As a result of CVA, the mahalanobis and procrustes distances were 2.9216 (P<0.0001) and 0.0645 (P=0.0035), respectively. Figure 4 shows the frequency graph obtained as a result of this test. The graph showed two female individuals in the group of males. More than 90% of the individuals were grouped correctly. There were differences between female and male goat astragalus bones at LM8, LM9, LM10, and LM11. These landmarks represented the mediopoximal portion of the astragalus. The proximal part of the astragalus was wider in males than in females (Figure 5).

According to the cross validation scores in DFA, 8 female individuals and 7 male individuals were incorrectly grouped (Figure 6). Females and males were grouped correctly by 50% and 65%, respectively. According to these results, sex factor had a limited grouping effect on astragalus shape.

DISCUSSION

Geometric morphometry and the related analyses allowed to examine the differences between the astragalus bones of male and female goats. The results revealed the shape of the astragalus in goats, while the allometric effect of size on the shape of the astragalus was not statistically significant. According to the results, the shape of the astragalus was found in the medioproximal part of the astragalus between male and female individuals, and the proximal part of the astragalus was wider in male goats than in females. When male and female comparative studies with linear measurements in the literature were examined, it was observed that many bones including the astragalus were morphologically wider in male individuals among human beings (Bilge, 2008; Bass, 1995). The current study conducted by using geometric morphometry support the studies using linear measurements in the literature in this regard.

Sorrentino and colleagues (2020), conducted a study using the geometric morphometric technique on a total of 98 human astragalus, (44 females and 54 males) from different geographical locations to investigate the role of shape, form and size in determining sex. They also demonstrated that the fragmented astragalus can be reconstructed. In the study, significant differences were found in sex dimorphism between astragalus from Sassari and Bologna regions and astragalus from New York and Bologna regions, while there was no significant difference in sexual dimorphism in the comparison between Sassari and New York regions. These results suggested that a population-specific approach should be used to assess sexual dimorphism in the human astragalus (Sorrentino et al. 2020). In addition, the data of the current study supported studies using traditional linear measurements to determine sex (Bidmos and Dayal, 2004; Lee et al., 2012a). In the present study, even though there were differences in some LM points in terms of sexual dimorphism, it was understood that the sex factor had a limited grouping effect on astragalus shape.

The morphological and morphometric features of bones may differ in certain populations. This situation is important for surgical operations. There are studies in the literature in which the talus bone is grouped into different types according to joint characteristics in populations located in different geographies (Lee et al., 2012b; Azra et al., 2020). According to these studies, there are differences in the right and left hind leg joint types of the same individual. These differences in the joints also affect the movement of the joint (Boyan et al., 2016). There are studies in the literature showing that different locomotor behaviors have an effect on the shape of the bone (Vermeulen et al., 2022). For this reason, talus bones from the same side (right) were used as material in our study. According to the findings of our study, it was revealed that the talus bones of the right side of goats did not provide clear results in determining gender.

Haruda (2017) conducted a comparative study with both traditional morphometry and geometric morphometry to reveal the taxonomic differences of sheep and goat talus bone. According to the findings of this study, the talus bone of sheep varied in size. It was also determined that the talus of sheep was larger in size than that of goats. Talus variation between sheeps and goats has been described. In our study, whether the talus bone would be effective in determining gender in goats was investigated using geometric morphometry.

When the literature is examined, there are comparative studies on cranial bones in goats with geometric morphometry method (Yaprak et al., 2022; Parés-Casanova, 2015; Parés-Casanova and Domènech-Domènech, 2021), comparative studies on mandible (Demiraslan et al., 2020; Evcim 2020) and studies comparing the difference of astragalus between sheep and goat (Haruda, 2017). However, there is no study in the literature that examined the sexual dimorphism of the astragalus with geometric morphometry on goats. Therefore, the results obtained in the current study could not be compared with a study conducted on goats using geometric morphometry technique.

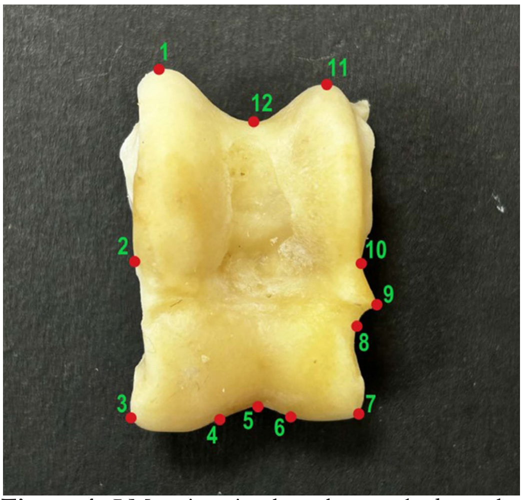

Figure 1. LM points in the talus marked on the photograph

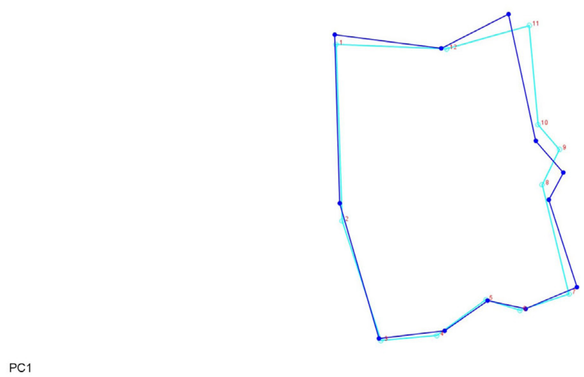

Figure 2. Line graph of the shape change of the talus in PC1 (Dark blue: mean shape, Light blue: variation)

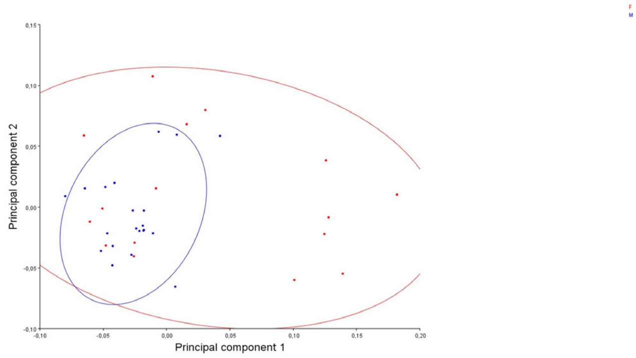

Figure 3. Scatter plot of PC1 of female and male individuals (Red: female, Blue: male)

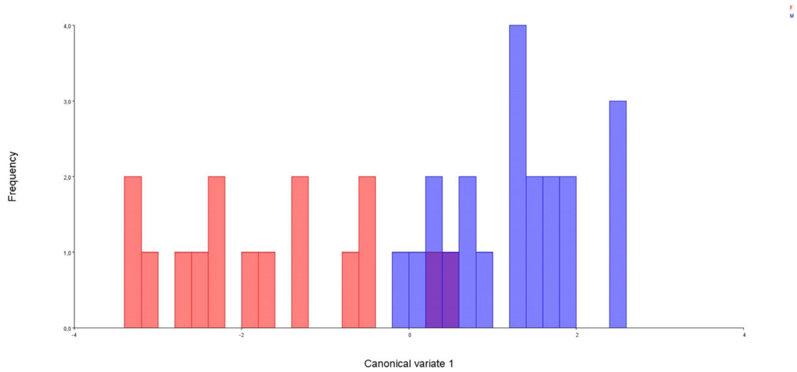

Figure 4. CVA graph of female and male individuals (Red: female, Blue: male)

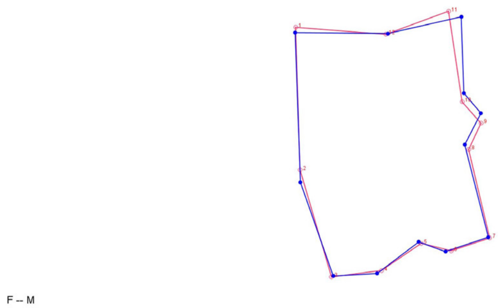

Figure 5. Line graph of female and male talus (Red: female, Blue: male)

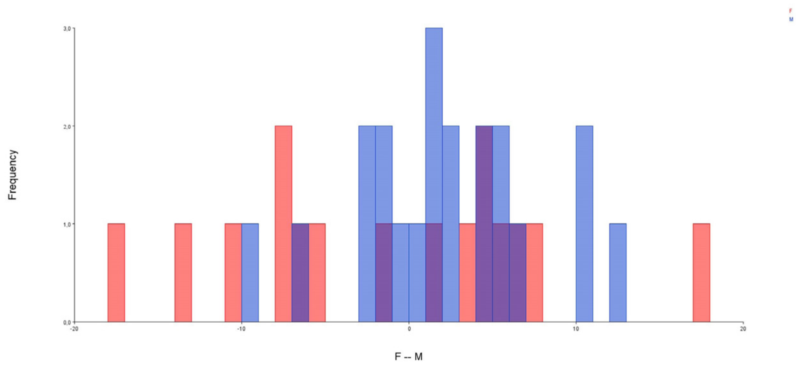

Figure 6. Graph of cross validation score in CFA for female and male individuals (Red: female, Blue: male)

CONCLUSION

In the present study, the sexual dimorphism of the astragalus bones of domestic goats was examined by geometric morphometry. It was found that the astragalus had a limited effect on sex determination. Thus, the study has supported the studies in the literature that have been conducted with linear measurements. In addition, it was determined that the size of the Astragalus had no significant effect on the shape of the astragalus. It is thought that the present study will contribute to the literature for future studies on small ruminants.

The limitations of the study are the lack of material and the unilateral examination of the bone.

DECLARATIONS

Ethics Approval

According to Article 8 of the Regulation on Working Procedures and Principles of Animal Experiments Ethics Committees dated 15 February 2014 and numbered 28914, Ethics Committee Approval is not required (E-93773921-020-354464).

Conflict of Interest

There is no conflict of interest in current practice.

Consent for Publication

Not applicable.

Author contribution

Idea, concept and design: YD

Data collection and analysis: TO

Drafting of the manuscript: YD

Critical review: ÖÖ

Data Availability

Not applicable.

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