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RESEARCH ARTICLE

Geometric Morphometric Analysis of Skull in Honamlı, Hair, Kilis and Saanen Goat Using Dorsal Landmarks

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ABSTRACT

The study aimed was to analyze the dorsal aspect of the skulls of Honamlı, Hair, Kilis, and Saanen goats by the geometric morphometric method. A total of 48 adult goat skulls, 6 male and 6 female, were used for each breed. After the skulls were photographed dorsally, 10 homologous landmarks were marked. As a result of our study, the degree of dorsal separation of the skulls according to sex was found to be limited. Nevertheless, significant separation was seen in the Honamlı skulls of females and in the Honamlı and Saanen skulls of males. This information may serve as a reference for the skull remains of ruminants.

Keywords: Geometric Morphometric, Goat, Landmark, Principal Component Analysis

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Honamlı, Kıl, Kilis ve Saanen Keçilerinde Kafatasının Dorsal Landmarklar Kullanarak Geometrik Morfometrik Analizi

ÖZ

Çalışmada geometrik morfometri yöntemi ile Honamlı, Kıl, Kilis ve Saanen keçisine ait kafataslarının dorsal yönden analizi amaçlandı. Her ırk için ayrı ayrı 6 erkek ve 6 dişi olmak üzere toplamda 48 adet ergin keçi kafatası kullanıldı. Kafatasları dorsal yönden fotoğraflandıktan sonra 10 adet homolog landmark işaretlendi. Çalışmamız neticesinde dorsal yönden cinsiyete göre kafataslarının birbirinden ayrılma derecesi sınırlı olarak saptandı. Buna rağmen dişilerde Honamlı kafataslarında, erkeklerde ise Honamlı ve Saanen kafataslarında belirgin ayrılmalar görüldü. Bu bilgilerin geviş getirenlere ait kafatası kalıntıları için referans oluşturabileceği düşünülmektedir.

Anahtar Kelimeler: Geometrik Morfometri, Keçi, Landmark, Temel Bileşenler Analizi

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INTRODUCTION

Domestic goats originate from the wild goat breeds Capra Prisca, Capra Falconeri, and Capra Aegagrus (Şengonca and Koşum 2005, Kaymakçı 2006, Günlü and Alaşahan 2010). Hair goat is a combined productive goat breed that is resistant to harsh climatic and environmental conditions and is the most numerous in Türkiye. (Sengonca and Kosum 2005, Günlü and Alaşahan 2010). Kilis goat is widely cultivated in the Southeastern Anatolia region. These goats are a goat breed with a robust body structure, long walking ability, high milk, and fertility. (Yalçın 1986, Kaymakçı and Aşkın 1997, Sengonca and Koşum 2005, Günlü and Alaşahan 2010). Honamlı goats have been bred pure in the Taurus Mountains for centuries. It was included in the scope of indigenous breeds taken under protection in Türkiye in 2005. (Karadağ and Soysal 2018). Saanen goats are bred in the Saanen valley of Switzerland. It is a goat breed with high fertility and milk yield. (Ceyhan and Karadağ 2009).

To increase the depth of information obtained with traditional morphometrics, a method called geometric morphometrics has emerged (Rohlf and Marcus 1993). In this method, shape differences that cannot be detected visually are detected by landmark (LM) coordinates. LMs, therefore, measure the amount of strain by exploiting differences in position between materials. (Kimmerle et al. 2008, Viscosi and Cardini 2011, Zelditch et al. 2012). In the literature review on goats, it was seen that there was a limited number of geometric morphometric method studies (Haruda 2017, Pares Casanova and Domenech Domenech 2021). The study aimed to analyze the skulls of four different goat breeds by geometric morphometry from the dorsal aspect.

MATERIALS and METHODS

In the study, 6 male and 6 female adult goat skulls were used separately for each breed. Skulls were obtained from meat plants in the regions where the breeds are distributed in Türkiye. Skulls are macerated for ease of processing. The skulls were photographed dorsally from a distance of 30 cm, focusing on the sutura frontonasalis. The obtained photographs were converted to tps files using TpsUtil (Version 1.79). Ten homologous landmarks were marked on the dorsal aspect of the skulls using the TpsDig2 program (Version 2.31). Landmarks marked from dorsal on the skulls of female Hair are shown in Figure 1. A Homologous landmark verification test was performed with TpsSmall (Version 1.34) program (Rohlf 2017). General Procrustes Analysis (superimposition) was performed on the skulls to eliminate variables such as size, position, and orientation (Slice 2005). PAST (Version 4.02) program was used for this analysis (Hammer et al. 2001).

Principal component analysis (PCA) was performedon the new coordinates obtained as a result of superimposition using the same program. Thus, the degree of separation of the skulls by race was determined (Zelditch et al. 2004). Discriminant function analysis (DFA) was performed with the MorphoJ program to show at which LMs level and in which direction the shape difference is (Klingenberg 2011). In the study, Relative Warp Analysis was performed with the TpsRelw (Version 1.70) program, consensus graphs of the groups were created and the distribution of the groups on the graph was tested with this analysis.(Rohlf 2017).Statistical analysis of LM coordinate values according to groups was performed with the ANOVA test in the PAST (Version 4.02) program.

RESULTS

In the study, PCA-1 explained 50.628% of the total shape variation in females and 42.268% in males. Scatter plots of individuals according to PCA and Relative Warp analysis are shown in Figure 2. The degree of separation between races was limited. The most prominent clusters were observed in the Honamlı skulls of females and the Honamlı and Saanen skulls of males.

The graph showing at which landmarks the shape difference is concentrated is shown in Figure 3. Accordingly, LM1, 3, 5, 6, 7, and 9 in females and LM1, 3, 4, 5, 6, and 7 in males were the LMs where variation was concentrated.

DFA plots are shown in Figure 4 and 5. According to DFA, female Honamlı skulls showed a shape difference compared to Hair skulls in a rostro-dorsal direction in LM1, 5, 7, and 10, caudo-ventral in LM3, 6, and 9, and rostro-ventral in LM4. Female Kilis skulls showed a difference in shape compared to Hair skulls in a caudo-dorsal direction at LM2, caudal at LM4, rostral at LM5, and rostro-dorsal at LM9. Female Saanen skulls showed a shape difference compared to Hair skulls in a rostro-ventral direction in LM1, rostro-dorsal in LM5 and 9, caudo-ventral in LM3 and 6, and caudo-dorsal in LM10. Female Kilis skulls showed a difference in shape compared to Honamlı skulls in a caudo-ventral direction in LM1, 7, and 10, rostro-dorsal in LM3, 6 and 9, caudo-dorsal in LM2 and 4, ventral in LM5 and rostro-ventral in LM8. Female Saanen skulls showed a difference in shape compared to Honamian skulls in a caudo-ventral direction in LM1, 7, and 10, rostro-dorsal in LM3, 6, and 9, caudo-dorsal in LM4 and rostro-ventral in LM5. Female Saanen skulls showed a shape difference compared to Kilis skulls in rostro-ventral direction in LM1, 2, and 4, caudo-ventral in LM3 and 6, rostro-dorsal in LM7, caudal in LM9 and caudo-dorsal in LM10.

According to DFA, male Honamlı skulls showed a difference in shape compared to Hair skulls in a caudo-dorsal direction in LM2, rostro-ventral in LM4 and 6, caudal in LM5, rostro-dorsal in LM7, caudo-ventral in LM9 and rostral in LM10. Male Kilis skulls showed a shape difference compared to Hair skulls in a caudo-ventral direction at LM1 and 7, rostro-dorsal direction at LM3 and 9, caudo-dorsal direction at LM5, and rostro-ventral direction at LM8. Male Saanen skulls showed a rostro-ventral shape difference in LM1, caudo-dorsal in LM4 and 10, and rostro-dorsal in LM5 and 9 compared to Hair skulls. Male Kilis skulls showed a difference in shape compared to Honamlı skulls in a caudo-ventral direction in LM1, 7, and 10; rostro-dorsal in LM2, 5, and 9; caudo-dorsal in LM3, 4, and 6; and rostro-ventral in LM8. Male Saanen skulls showed a shape difference compared to Honamlı skulls in a rostro-ventral direction in LM1 and 2, caudo-dorsal in LM3, 4, 6, and 10, rostro-dorsal in LM5 and 9, and caudo-ventral in LM7 and 8. Male Saanen skulls showed a shape difference compared to Kilis skulls in the rostral direction in LM1, rostro-ventral in LM2, caudo-ventral in LM3 and 6, caudo-dorsal in LM4, 9, and 10, and rostro-dorsal in LM5 and 7.

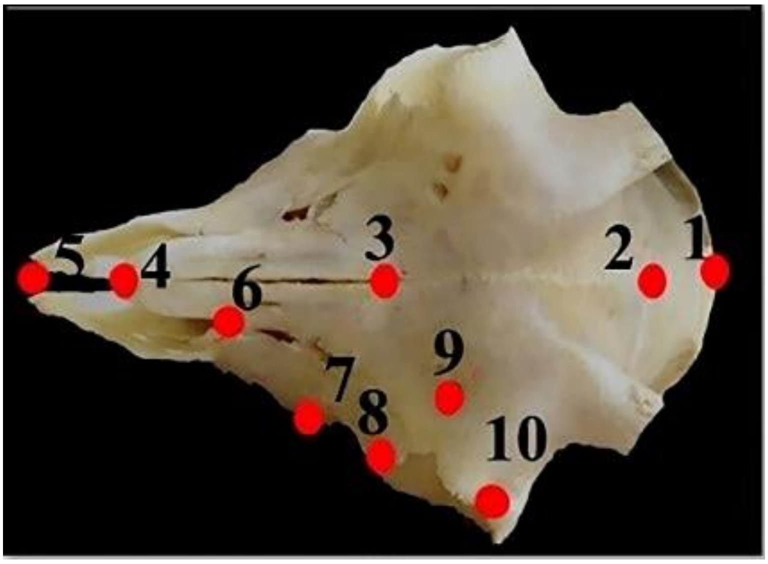

Figure 1: Landmarks marked from dorsal on the skulls of female Hair
(1: Protuberantia occipitalis externa, 2: The junction of sutura coronalis and sutura interfrontalis, 3: Median point of the Sutura frontonasalis, 4: Rostral end of sutura internasalis, 5: The rostral end of the fissura interincisiva, 6: Incisura nasoincisiva, 7: Tuber faciale, 8: Medial angle of the orbit, 9: Foramen supraorbitale, 10: Caudo-ventral corner of the margo supraorbitalis).

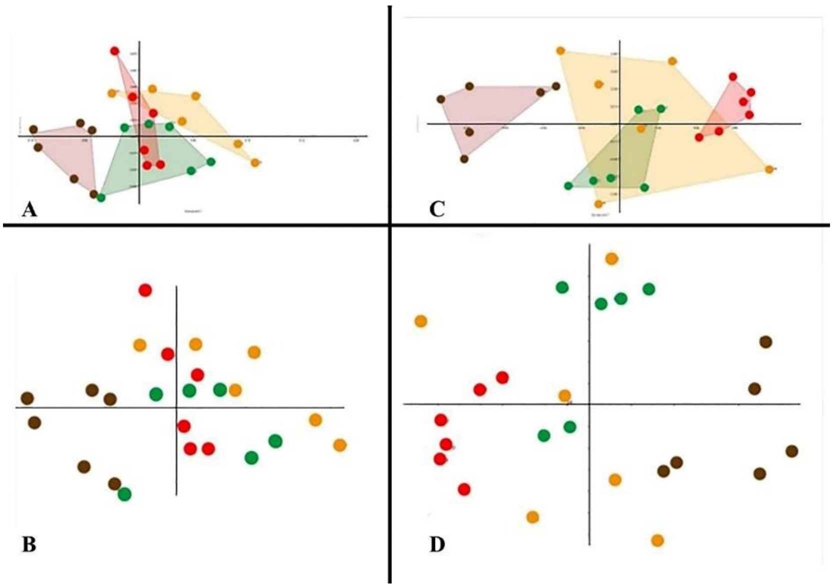

Figure 2: A. PCA plot for female, B. RWA plot for female, C. PCA plot for male, D. RWA plot for male. brown: Honamlı, green: Hair, orange: Kilis, red: Saanen

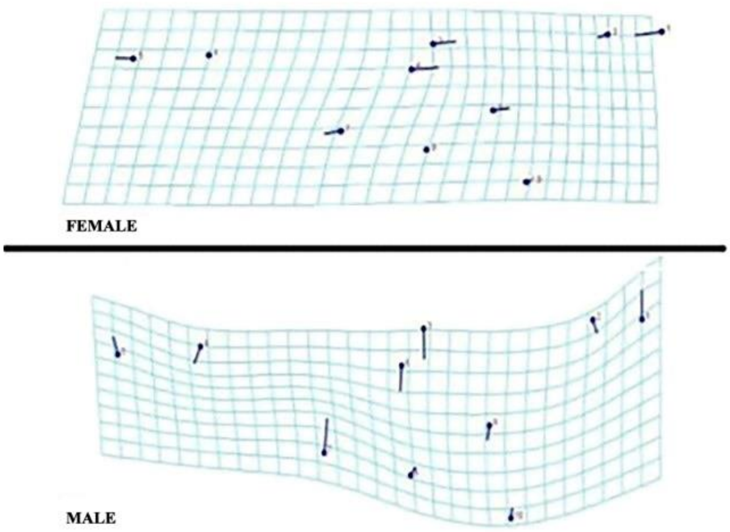

Figure 3: Transformation grid model of Honamlı, Hair, Kilis, and Saanen goat skulls according to the PC1.

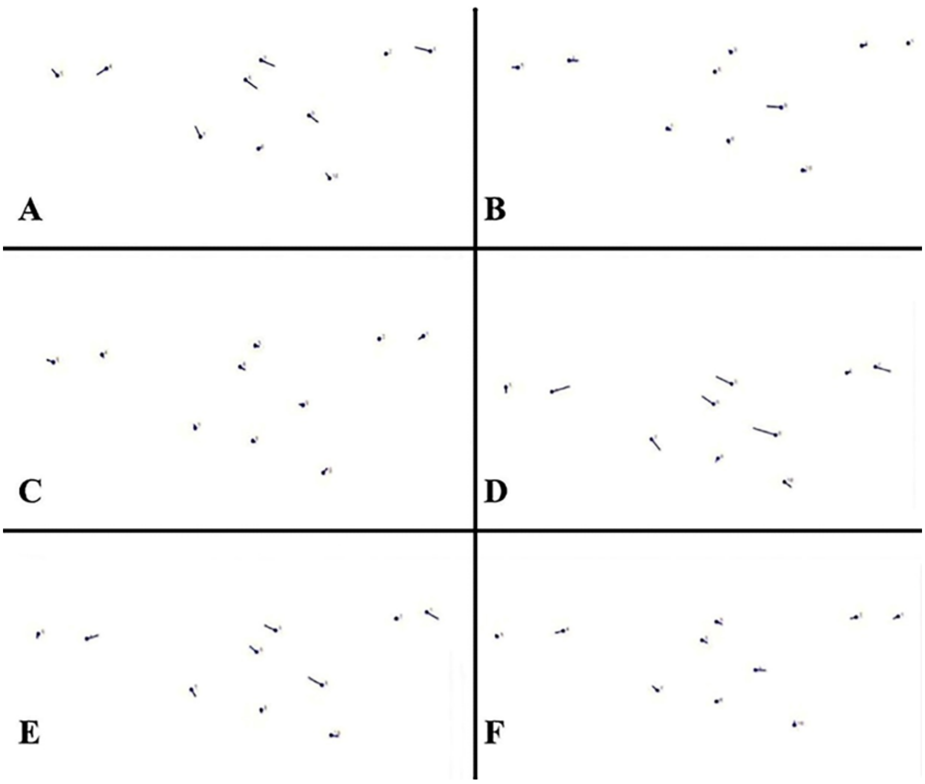

Figure 4: Graphs of discriminant function analysis of shape variation according to breed for female goats A. Hair-Honamlı, B. Hair-Kilis, C. Hair-Saanen, D. Honamlı-Kilis, E. Honamlı-Saanen, F. Kilis-Saanen.

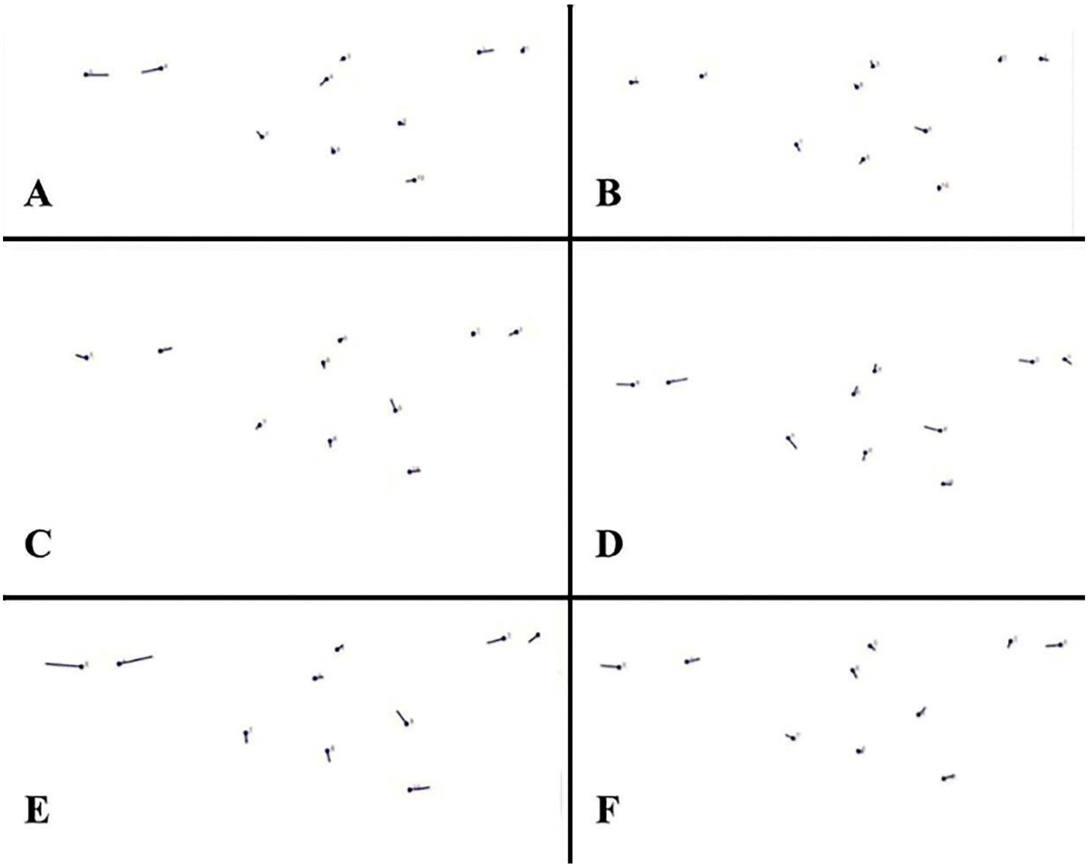

Figure 5: Graphs of discriminant function analysis of shape variation according to breed for male goats A. Hair-Honamlı, B. Hair-Kilis, C. Hair-Saanen, D. Honamlı-Kilis, E. Honamlı-Saanen, F. Kilis-Saanen.

DISCUSSION

In this study, we analyzed the skulls of breed-registered goats living in different geographical regions by geometric morphometric methods from the dorsal aspect. The overarching goal of the study was to determine whether racial dimorphism is also shaped in the dorsal skull. Preliminary findings from this study with a limited number of skulls showed that there is limited variation between breeds in the dorsal part of the goat skull.

Casanova and Miquel (2015), carried out a geometric morphometric study on the dorsal dorsum of the skulls of White Rasquera goats for sex discrimination. In their study, they reported that PCA-1 explained 41.7% of the shape variation. In our study, PCA-1 explained 50.628% of the total shape variation in females and 42.268% in males in the analysis performed to differentiate skulls of different races within the same sex. Casanova and Miquel (2015), reported that White Rasquera breed goats showed sexual dimorphism in a dorsal directional geometric morphometry study of the skull. In our study, the degree of dorsal separation of the skulls by race was limited.

Demiraslan et al. (2021), in their geometric morphometric study on the mandible of Honamlı and Hair goats, reported that Hair goats showed a very distinct gender difference compared to Honamlı goats, and that male goats were clearly clustered compared to female goats in terms of race factor. In our study, the degree of dorsal separation of skulls by breed was limited and the most prominent clustering was seen in Honamlı skulls in females and Honamlı and Saanen skulls in males.

Demircioğlu et al. (2021), conducted a geometric morphometric study on the skull and mandible of Awassi sheep. For this purpose, they analyzed the skull from 17 dorsal, 16 left lateral and 20 mandible s from 20 left lateral photographs. They reported that the first principal component explained 37.719% and 44.238% of the total shape variation in the dorsal and left lateral directions of the skull of Awassi sheep, respectively. In the mandible, they stated that the first principal component explained 24.92% of the total shape difference. In the analysis of the skulls from the dorsal and left lateral direction, they reported that there was a significant variation between the sexes, but no such variation in the mandibles. In our study, the skulls of Honamlı, Hair, Kilis, and Saanen goats were examined dorsally between the breeds of the

same sex. PCA-1 explained 50.628% of the total shap variation in females and 42.268% in males. Dorsally, the degree of separation of skulls by race was limited.
Demircioğlu et al. (2022), compared the skulls of Hamdani and Awassi sheep using dorsal and lateral LMs. In the dorsal and lateral comparison of the breeds, they reported that the first principal components explained 41.905%, and 39.078% of the total shape variations, respectively. In our study, Honamlı, Hair, Kilis, and Saanen skulls were evaluated dorsally at the same time, considering gender differences. PCA-1 value was 50.628% in females and 42.268% in males. Demircioğlu et al. (2022), reported that Hamdani skulls were clustered to the right of the y coordinate and Awassi skulls to the left of the y coordinate according to PCA graph data from dorsal and lateral. In our study, in the dorsal evaluations of female Honamlı, Hair, Kilis, and Saanen skulls, it was observed that all female Honamlı skulls were clustered to the left of the y coordinate, while female Hair, Kilis and Saanen skulls were mostly clustered to the left of the y coordinate. In the dorsal view of male Honamlı, Hair, Kilis, and Saanen skulls, it was observed that all male Honamlı skulls were clustered to the left of the y coordinate, all male Saanen skulls were clustered to the right of the y coordinate, and male Hair skulls were clustered mostly above the x coordinate. Male Kilis skulls showed a scattered distribution. Demircioğlu et al. (2022), according to the consensus graphic data they obtained, reported that vector variation was concentrated in LM3, 8, 9, and 10 from the dorsal and LM1, 4, 5, 7, 8, 9, 10, 11, and 12 from the lateral. In our study, in female Honaml, Hair, Kilis, and Saanen skulls, vectorial variation was concentrated in LM1, 3, 5, 6, 7, and 9 dorsally. In male Honamlı, Hair, Kilis and Saanen skulls, vectoral variation was concentrated in LM1, 3, 4, 5, 6 and 7 from the dorsal side.
Yalçın and Kaya (2009), used the skull bones of adult and female Anatolian wild sheep and adult and female Akkaraman sheep and examined them basally and dorsally. The PCA-1 values of the dorsal and basal skull bones of both species were 58.55% and 65.93%, respectively. In the PCA graphs made from the dorsal and basal sides, it was reported that Akkaraman sheep skull bones were clustered to the left of the y coordinate, while Anatolian wild sheep skull bones were clustered to the right. As a result of the analysis they reported that a significant variation occurred between the skull bones of both species. In our study, PCA-1 values of male and female Honamlı, Hair, Kilis, and Saanen goats were found to be 50.628, and 42.268%, respectively. According to the PCA plot from the dorsal side, all female Honamlı goat skulls were clustered to the left of the y coordinate, while female Hair, Kilis, and Saanen skulls were clustered to the right of the y coordinate. In the dorsal view of male Honamlı, Hair, Kilis, and Saanen skulls, it was observed that all male Honamlı skulls were clustered to the left of the y coordinate, all male Saanen skulls were clustered to the right of the y coordinate, and male Hair skulls were clustered mostly above the x coordinate. Male Kilis skulls showed a scattered distribution. In our study, the degree of dorsal separation of Honamlı, Hair, Kilis, and Saanen goat skulls was limited and the most prominent clustering was seen in Honamlı skulls in females and Honamlı and Saanen skulls in males.
Yaprak et al. (2022), examined male and female Honamlı, Hair, Kilis, and Saanen skulls from basal. They found PCA-1 values of 30.319 % for females and 28.164 % for males. They reported that there was a limited separation between breeds and the most prominent clusters were between Kilis and Saanen skulls in females and between Honamlı and Kilis skulls in males. In our study, male and female Honamlı, Hair, Kilis, and Saanen skulls were examined dorsally. PCA-1 explained 50.628% of the total shape variation in females and 42.268% in males. There was a limited separation between breeds and the most significant clustering was observed in Honamlı skulls in females and Honamlı and Saanen skulls in males. Yaprak et al. (2022), reported that vectorial variation was concentrated in LM1, LM9, and LM10 in females and LM5, LM6, LM7, and LM8 in males. In our study, LM1, 3, 5, 6, 7, and 9 in females and LM1, 3, 4, 5, 6, and 7 in males were the LMs where variation was concentrated.

CONCLUSION

In this study, for the first time, the skulls of Honamlı, Hair, Kilis, and Saanen goats were analyzed for the presence of dorsal breed dimorphism by geometric morphometric methods. In this study, the first inferences were obtained that racial discrimination among goats from the dorsal aspect of the skull may be possible. It may be suggested that the findings of the study should be further elaborated by including more skulls and different breeds of goats. Despite all these, it is thought that the data presented in this study will contribute to the morphometric studies to be carried out in ruminantia skulls

Conflict of Interest: The authors declared that there are no actual, potential or perceived conflicts of interest for this article.

Authors Contribution Rate: The authors declared that they contributed equally to the article.

Ethical Approval: This study is not subject to HADYEK's permission in accordance with Article 8 (k) of the "Regulation on Working Procedures and Principles of Animal Experiments Ethics Committees".

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Explanation: It is summarized from the author's doctoral thesis titled "Analysis of Cranium in Kil, Kilis, Honamlı and Saanen Goats by Geometric Morphometric Methods".

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