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A MORPHOMETRIC STUDY OF METAPODIUM IN BARDHOKA SHEEP

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Abstract. In this study, it was aimed to determine the osteometric features on the metapodium bones of Bardhoka sheep which is native to Kosovo. Twenty-four (12 male, 12 female) healthy adult sheep weighing between 48 and 72 kg were used in the study. The difference between male and female was found to be statistically significant in morphometric measurements except for DEM (Antero-posterior diameter of the external trochlea of the medial condyle) for metacarpus. For metatarsus, the difference in all measurements between male and female was statistically significant. The highest correlation was found between Bd (Width of distal end) and WCM (Medio-lateral width of the medial condyle) measurements for metacarpus. The highest correlation between male and female for metatarsus was found between DIM (Antero-posterior diameter of the internal trochlea of the medial condyle) and Dd (Depth of distal end) measurements. It was seen that the metacarpus CV% values of female sheep ranged from 3.16% to 9.29%, and the metatarsus values ranged from 2.95% to 6.60%. In male sheep, these values were between 2.95% and 8.04% for metacarpus, and between 2.82% and 8.83% for metatarsus. The statistical difference between female and male index 3 (Bd / GL * 100) was found to be significant.

Keywords: *Bardhoka sheep, metapodium, osteometric, veterinary anatomy.*

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1. Introduction

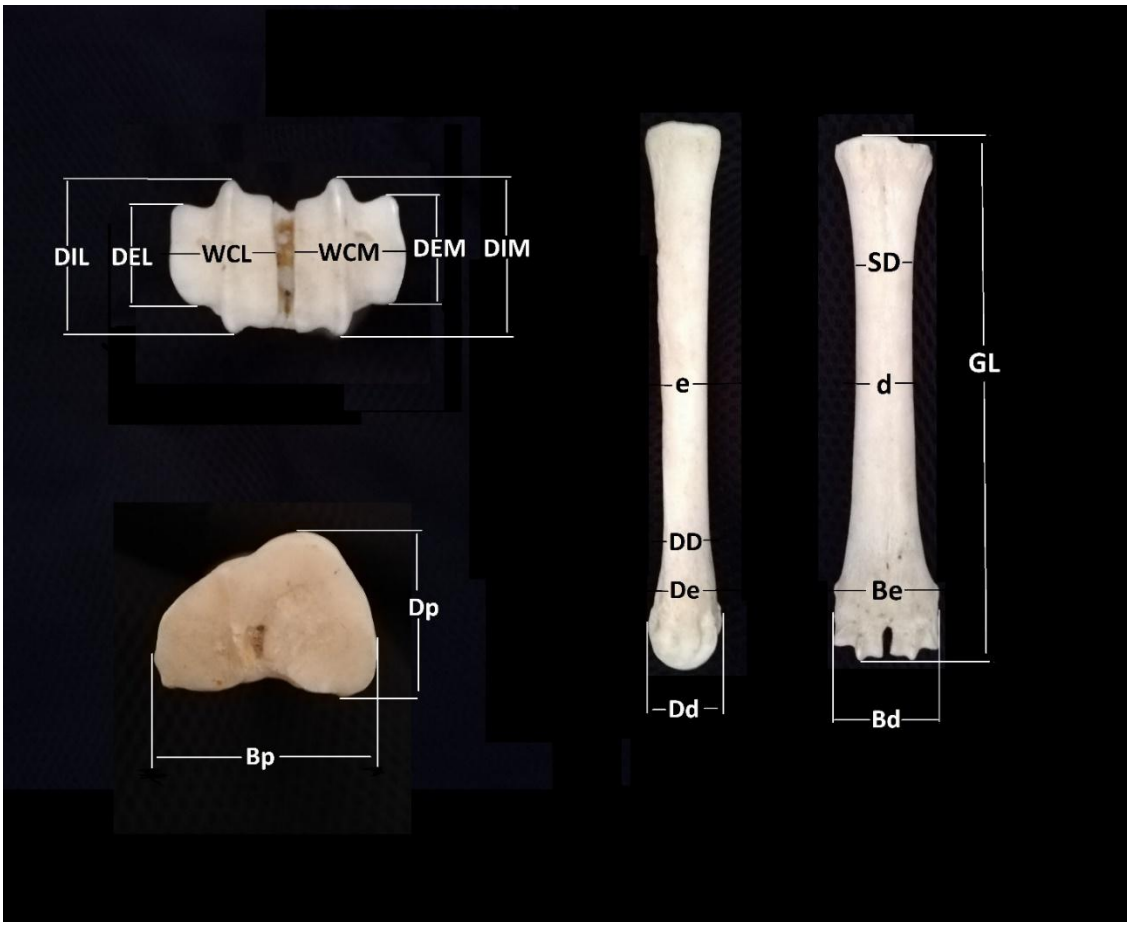
Bardhoka sheep is a local sheep breed in Kosovo. This breed is used for milk and meat consumption in Kosovo. It is one of the races with the highest milk yield among the Balkan countries. It has an average height of 64 centimeters (Bytyqi *et al*., 2014; 2015; Ćinkulov *et al.*, 2008). There are a limited number of anatomy studies on this breed (Gündemir *et al*., 2020).

Sheep have a wide usage area for human needs such as meat, milk and wool. In this respect, it has lived with people in many parts of Europe since the past and witnessed many historical changes (Bläuer *et al*., 2019; Rannamäe *et al*., 2016). In particular, the remains of sheep obtained as a result of excavations can provide information about the conditions of the day. For this reason, especially metapodium bones have been investigated in many excavations (Pazvant *et al*., 2015; Onar *et al*., 2015a; Ince *et al*., 2018). For this purpose, there are various studies that help to estimate the animal's body characteristics by using the bones found in the excavations (Demiraslan *et al*., 2019; Onar *et al.*, 2015b). In this study, it was aimed to make the osteometric features on the metapodium bones of Bardhoka sheep which is native to Kosovo. We obtained the difference between the male and female sheep. We also tried to reveal the differences between the Bardhoka sheep breed and other sheep breeds. It is

thought that the obtained results will help in the taxonomy of the bones obtained as a result of the excavations.

2. Materials and Methods

Twenty-four (12 male, 12 female) healthy adult sheep weighing between 48 and 72 kg were used in the study. Metapodium bones were collected after slaughter of these sheep in Kosovo. Bones removed from soft tissue were boiled in saline for 5 hours. Then it was allowed to dry after being kept in hydrogen peroxide (%50) for half an hour. Digital caliper (150 mm) was used for measurements.



GL: Greatest length, **Bp:** Width of proximal end, **Dp:** Depth of proximal end, **d:** Mid-shaft width of diaphysis, **e:** Mid-shaft depth of diaphysis, **SD:** Smallest width of diaphysis, **DD:** Smallest depth of diaphysis, **Bd:** Width of distal end, **Dd:** Depth of distal end, **Be:** Greatest width of metaphysis, **De:** Greatest depth of metaphysis, **DIM:** Antero-posterior diameter of the internal trochlea of the medial condyle, **DEM:** Antero-posterior diameter of the external trochlea of the medial condyle, **DIL:** Antero-posterior diameter of the internal trochlea of the lateral condyle, **DEL:** Antero-posterior diameter of the external trochlea of the lateral condyle, **WCM:** Medio-lateral width of the medial condyle, **WCL:** Medio-lateral width of the lateral condyle

Fig. 1. Measurement of metacarpus and metatarsus

Measurements from bone (Guintard &Lallemand, 2003; Davis, 1996; Pourlis *et al.*, 2017):

GL: Greatest length
Bp: Width of proximal end
Dp: Depth of proximal end
d: Mid-shaft width of diaphysis
e: Mid-shaft depth of diaphysis
SD: Smallest width of diaphysis
DD: Smallest depth of diaphysis
Bd: Width of distal end
Dd: Depth of distal end
Be: Greatest width of metaphysis
De: Greatest depth of metaphysis
DIM: Antero-posterior diameter of the internal trochlea of the medial condyle
DEM: Antero-posterior diameter of the external trochlea of the medial condyle
DIL: Antero-posterior diameter of the internal trochlea of the lateral condyle
DEL: Antero-posterior diameter of the external trochlea of the lateral condyle
WCM: Medio-lateral width of the medial condyle
WCL: Medio-lateral width of the lateral condyle

SPSS program (SPSS for Windows, version 21.0) was used for statistical analysis. One-Sample T Test was applied to obtain the mean, maximum and minimum values. Independent-Samples T Test was used to reveal the differences between the groups. The statistically significant ($P < 0.001$) differences between the groups were used in discriminant analysis. Variation coefficient was calculated separately for metatarsus and metacarpus (CV%: Standard deviation/Mean*100).

Three indices were used to reveal the difference between the groups (Pazvant at al. 2015; Ince at al. 2018; Onar at al. 2008):

Metapodial Slenderness index (index 1): SD/GL*100
Index 2: Bp/GL*100
Index 3: Bd/GL*100

This study was accepted by Food and Veterinary Agency, Office of Prime Minister, Republic of Kosovo (Decision number: 3918-7).

3. Results

The mean, standard deviation, minimum and maximum values of the metacarpus measurements are given in Tables 1 and 2 for both male and female animals. According to these measurements, the difference between male and female was found to be statistically significant in morphometric measurements except for DEM for metacarpus. For metatarsus, the difference in all measurements between male and female was statistically significant (table 3, table 4). It was also observed that all measurements in male animal were higher than females.

Table 1. Morphometric values of metacarpi

Sex	Measurement	Weigh (kg)	GL	Bp	Dp	d	e	SD	DD	Bd
	Mean	53.08	139.19	26.18	19.5	14.88	11.11	16.11	12.92	27.22
Female	SDT	3.18	6.61	1.15	1.23	0.92	0.56	0.9	1.04	0.86
(cm)	Min	48	122.06	24.71	18.01	13	10.02	15.12	11.61	25.9
	Max	58	146.77	27.8	21.38	16.47	12.06	17.83	15.52	29.02
	Mean	67.83	148.48	28.72	21.1	16.75	12.98	17.9	14.05	30.49
Male	SDT	4.39	8.05	2.02	1.46	1.06	0.86	1.05	1.13	1.91
(cm)	Min	55	135.12	26.45	19.5	14.87	11.63	16.04	12.7	28.46
	Max	72	161.36	31.61	23.72	18.84	14.91	19.52	15.58	35.6
P value		***	**	**	**	***	***	***	*	***

SDT: Standard deviation. **NS:** Not significant. ***:** P < 0.05. ****:** P < 0.01. *****:** P < 0.01.

Table 2. Morphometric values of metacarpi

Sex	Measurement	Dd	Be	De	DIM	DEM	DIL	DEL	WCM	WCL
	Mean	17.79	28.63	14.84	15.01	12.49	14.83	11.71	12.6	12.2
Female	SDT	0.68	1.05	0.52	0.81	1.16	0.78	0.63	0.44	0.54
(cm)	Min	16.64	26.68	14.16	13.77	11.1	13.75	10.05	11.95	11.4
	Max	19.24	29.95	16.07	16.48	15.5	16.12	12.45	13.21	13.03
	Mean	19.3	32.39	17.79	16.37	12.98	16.19	12.43	14.24	13.64
Male	SDT	0.57	1.64	1.32	0.6	0.4	0.63	0.65	0.98	0.55
(cm)	Min	18.36	30.01	15.72	15.66	12.14	14.94	11.66	13.42	12.63
	Max	20.25	35.75	19.59	17.76	13.6	17.11	14.05	17.17	14.76
P value		***	***	***	***	NS	***	*	***	***

SDT: Standard deviation. **NS:** Not significant. ***:** P < 0.05. ****:** P < 0.01. *****:** P < 0.001.

Table 3. Morphometric values of metatarsi

Sex	Measurement	GL	Bp	Dp	d	e	SD	DD	Bd
	Mean	147.35	22.65	22.11	12.95	12.34	14.03	14.26	25.64
Female	SDT	6.73	0.72	1.03	0.7	0.62	0.87	0.79	1.01
(cm)	Min	132.34	21.43	20.39	12.27	11.2	12.85	12.9	23.94
	Max	158.14	23.85	23.95	14.74	13.31	16.28	15.61	27.61
	Mean	158.85	24.37	24.53	13.99	14.22	15.06	16.19	28.08
Male	SDT	7.71	1.02	0.72	0.77	1.07	0.86	1.43	0.98
(cm)	Min	146.69	22.48	23.22	12.9	12.74	13.74	14.19	26.69
	Max	172.83	25.74	25.9	15.49	16.32	16.29	18.95	29.98
P value		**	***	***	**	***	**	**	***

SDT: Standard deviation. **NS:** Not significant. ***:** P < 0.05. ****:** P < 0.01. *****:** P < 0.001.

Table 4. Morphometric values of metatarsi

Sex	Measurement	Dd	Be	De	DIM	DEM	DIL	DEL	WCM	WCL
	Mean	17.34	26.37	15.21	14.59	11.15	14.62	11.22	11.81	11.57
Female	SDT	0.8	0.78	0.87	0.75	0.49	0.7	0.55	0.78	0.61
(cm)	Min	16.14	25.27	13.86	13.33	10.61	13.8	10.33	10.45	10.36
	Max	18.81	27.48	17.08	15.96	12.26	16.04	12.01	12.91	12.37
	Mean	18.82	29.27	17.74	15.87	12.16	15.78	11.89	13.35	12.4
Male	SDT	0.53	1.27	1.3	0.49	0.37	0.44	0.41	0.51	0.49
(cm)	Min	17.71	26.62	16.12	15.04	11.4	14.97	11.24	12.54	11.43
	Max	19.57	30.89	19.5	16.63	12.8	16.41	12.41	14.28	13.3
P value		***	***	***	***	***	***	**	***	**

SDT: Standard deviation. **NS:** Not significant. ***:** P < 0.05. ****:** P < 0.01. *****:** P < 0.001.

Metatarsus and metacarpus measurement values regardless of sex are given in tables 5 and 6. There was no statistically significant difference between Dd, De, DIM, DIL and DEL values.

Table 5. Morphometric values of metatarsi and metatarsus

Bone	Measurement	GL	Bp	Dp	d	e	SD	DD	Bd	Dd
	Mean	143.84	27.45	20.3	15.81	12.04	17	13.48	28.86	18.54
	SDT	8.63	2.07	1.55	1.36	1.19	1.32	1.21	2.21	0.98
Metacarpus (cm)	Min	122.06	24.71	18.01	13	10.02	15.12	11.61	25.9	16.64
	Max	161.36	31.61	23.72	18.84	14.91	19.52	16.38	35.6	20.25
	Mean	153.1	23.51	23.32	13.47	13.28	14.55	15.22	26.86	18.08
	SDT	9.2	1.23	1.51	0.89	1.28	1	1.5	1.58	1
	Min	132.34	21.43	20.39	12.27	11.2	12.85	12.9	23.94	16.14
Metatarsus (cm)	Max	172.83	25.74	25.9	15.49	16.32	16.29	18.95	29.98	19.57
P value		**	***	***	***	**	***	***	**	NS

SDT: Standard deviation. **NS:** Not significant. ***:** P < 0.05. ****:** P < 0.01. *****:** P < 0.001.

Table 6. Morphometric values of metatarsi and metatarsus

Bone	Measurement	Be	De	DIM	DEM	DIL	DEL	WCM	WCL
	Mean	30.51	16.32	15.69	12.73	15.51	12.07	13.42	12.92
Metacarpus (cm)	SDT	2.34	1.79	0.98	0.89	0.98	0.73	1.12	0.91
	Min	26.68	14.16	13.77	11.1	13.75	10.05	11.95	11.4
	Max	35.75	19.59	17.76	15.5	17.11	14.05	17.17	14.76
	Mean	27.82	16.47	15.23	11.65	15.2	11.56	12.58	11.98
Metatarsus (cm)	SDT	1.8	1.68	0.9	0.67	0.83	0.58	1.02	0.69
	Min	25.27	13.86	13.33	10.61	13.8	10.33	10.45	10.36
	Max	30.89	19.5	16.63	12.8	16.41	12.41	14.28	13.3
P value		***	NS	NS	***	NS	NS	*	***

SDT: Standard deviation. **NS:** Not significant. ***:** P < 0.05. ****:** P < 0.01. *****:** P < 0.001.

For metacarpus, discriminant and correlation analysis tests were applied to evaluate the distinction between male and female. The highest correlation was found between Bd and WCM measurements (Correlation value: 0.913). One discriminant function was found. Canonical correlation was found to be 0.93. The square of the Canonical correlation was calculated It was determined that this function was able to identify 86.5% of the male and female individuals.

Discriminant formula for the identification of individuals between male and female for metacarpus:

Z: -25.565+1.019(e)+0.815(De)

As in the examples, when the values of the animal are written in place, if the result is positive, the animal is defined as male and the negative as female;

Z: -25.265+(1.019*11.21) +(0.815*14.99): -1.625 (female sample)

Z: -25.265+(1.019*13.34) +(0.815*16.05): 1.405 (male sample)

However, as in the square of canonical correlation, this formula has an 86.5% chance of success. In other words, it was determined that there were 3 incorrect results in the sample of 24 animals used.

The highest correlation between male and female for metatarsus was found between DIM and Dd measurements (Correlation value: 0.886). One discriminant function was found. Canonical correlation was found to be 0.86. The square of the Canonical correlation was calculated It was determined that this function was able to identify 74% of the male and female individuals.

Discriminant formula for the identification of individuals between male and female for metatarsus:

Z: -31.643+669(Dp)+0.576(Be)

Variation coefficients of morphometric data were also calculated. Metacarpus and metatarsus CV% values of female and male Bardhoka sheep are given in Table 7. According to these data, it was seen that the metacarpus CV% values of female sheep ranged from 3.16% to 9.29%, and the metatarsus values ranged from 2.95% to 6.60%. In male sheep, these values were between 2.95% and 8.04% for metacarpus, and between 2.82% and 8.83% for metatarsus.

Table 7. CV% values of metacarpus and metatarsus

Measurement	Metacarpus		Metatarsus	
	Female (cm)	Male (cm)	Female (cm)	Male (cm)
GL	4.75	5.42	4.57	4.85
Bp	4.39	7.03	3.18	4.19
Dp	6.31	6.92	4.66	2.94
d	6.18	6.33	5.41	5.50
e	5.04	6.63	5.02	7.52
SD	5.59	5.87	6.20	5.71
DD	8.05	8.04	5.54	8.83
Bd	3.16	6.26	3.94	3.49
Dd	3.82	2.95	4.61	2.82
Be	3.67	5.06	2.96	4.34
De	3.50	7.42	5.72	7.33
DIM	5.40	3.67	5.14	3.09
DEM	9.29	3.08	4.39	3.04
DIL	5.26	3.89	4.79	2.79
DEL	5.38	5.23	4.90	3.45
WCM	3.49	6.88	6.60	3.82
WCL	4.43	4.03	5.27	3.95

Three different indexes for metacarpus and metatarsus were applied between male and female groups (table 8). According to these results, the statistical difference between female and male index 3 (Bd / GL * 100) was found to be significant.

Table 8. Indices values of metacarpus and metatarsus

		Female		Male		
Bone	**İndices**	**Mean**	**SDT**	**Mean**	**SDT**	**P value**
Metacarpus (cm)	1	11.59	0.71	12.07	0.62	NS
	2	18.83	0.95	19.35	1.03	NS
	3	19.59	0.86	20.55	1.09	P < 0.05
Metatarsus (cm)	1	9.54	0.83	9.49	0.44	NS
	2	15.39	0.52	15.36	0.51	NS
	3	17.43	1.03	17.70	0.57	NS

SDT: Standard deviation. **NS:** Not significant.

4. Discussion and Conclusion

In our study, morphometric data of Bardhoka race of Kosovo race were taken, statistical analysis was performed and CV% values were calculated. In metacarpus measurements, the highest CV% value for females was found to be DEM, and for metatarsus WCM. In men, the highest CV% values for both metacarpus and metatarsus were found to be DD. As in our previous study in Shetland sheep, the highest CV% for metacarpus in females was reported as DEM (Davis, 1996). The highest CV% value for female metacarpus in Morkaraman sheep breed, which is one of the Turkish local sheep breeds, was Bd, Be in Tuj sheep breed and SD in Kıvırcık sheep breed (Davis, 1996; Demiraslan *et al*., 2015). In males, the highest CV% value was found to be DD in both metacarpus and metatarsus of the Bardhoka race. Despite this, the highest value in morkaraman was De, in Tuj was DIL and in Kıvırcık was SD is reported to be. (Demiraslan *et al*., 2015; Bacinoglu, 2006). In a study of 215 sheep samples, the highest CV% for male and female in metacarpus and metatarsus was reported to be d (Guintard & Lallemand, 2003). In this study, the highest values in metatarsus females were found to belong to WCM as in female Tuj sheep breeds. For the metatarsus, the Be measurement in females and the De measurement in males were higher in morkaraman sheep breeds (Demiraslan *et al*., 2015). For the metatarsus, it was reported that CV% of De measurements in female Kıvırcık sheep breed were high. (Bacinoglu, 2006). In another study, the osteometric examination of sheep and goat bones revealed during the archeological excavations of the Yenikapı Metro and Marmaray regions of Istanbul was performed (Pazvant *et al*., 2015). In this study, it was reported that CV% value was higher in DD measurements for metatarsus and metacarpus bones. CV% values are considered to be lower in homogeneous samples. Generally, this rate was found to be higher in the excavation studies than in the uniform race studies. In addition, it is seen that CV% values in DD measurements are high in samples with high number of animals.

It was reported that the GL value for the metacarpus bones extracted during the archeological excavations of Yenikapı Metro and Marmaray regions in Istanbul was 124.91 cm (Pazvant *et al.*, 2015). It was reported that the average GL measurements of female Morkaraman sheep with an average of 32.86 kilograms was 137.98, and that of female Tuj sheep with an average of 32.09 kilograms was 133.15 cm (Demiraslan *et al.*, 2015). In the Bardhoka sheep breed, the mean of metacarpus GL measurements of the female with an average weight of 53.08 kg were found to be 139.19 and the mean of

metacarpus GL measurements of the male with an average weight of 67.83 kg were found to be 148.48. In another study, the mean GL measurements of sheep without distinction between males and females were reported to be 149.71 (Pourlis *et al.*, 2017). The mean GL measurements of this study were found to be higher than the GL measurements of Bardhoka breed sheep. However, it is thought that morphometric measurements of these comparisons would be more accurate in comparing the data such as body weight and body length.

It was seen that CV% of Bd values were low for metacarpus and metatarsus. In addition, a statistically significant difference was found between male and female sheep for these values ($P < 0.01$). However, Bd measurement value is not included in the formulas obtained from discriminant analysis. In discriminant analysis, e and de values for metacarpus and Dp and Be values for metatarsus were differentiated. In addition, it was found that the correlation between Bd and WCM values was highest for metacarpus and the correlation between DIM and Dd values was highest for metatarsus. In this study it was performed, it was seen that the differential values obtained for each test were different. In this respect, we think that it would be more accurate to perform all tests that can be performed in morphometric measurements. We know that the number of samples should be high especially for discriminant analysis. However, the number of Bardhoka sheep breeds is known to be low. And it was found that it was difficult to obtain material related to this race during the study.

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