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Original Article

Three-Dimensional Modelling of Computed Tomography Images of Limb Bones in Germany Mast Goose (Anser anser)

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ABSTRACT

The aim of this study is to examine the osteometric measurements of the long and short bones in the fore and hind extremities of German mast geese using 3d reconstruction technique. For this purpose, 10 (5 female and 5 male) German mast goose were used. After the dissection process of the geese was completed, computerized tomography was taken and the reconstruction process was completed. In the measurements made, it was observed that male were longer than female in the GL parameter in all bones. Bd parameter and surface area in the humeral bone were statistically significant (p<0.05). The measurement points of the femur bone were analyzed, statistical significance was found in LM, BP, SC and volume parameters (p<0.05). The parameter Dp was highly significant (p<0.01). As a result, since this study is the first 3D study in geese, it will contribute to the taxonomy and the differences between the birds with the measurements made.

INTRODUCTION

The mast goose is a native goose breed originating from Germany. The mast goose has been recorded as a fast-growing goose species (Çelebi, 2020). Mast goose has white feathers, a large body structure, an orange beak, and pinkish feet.

Mast geese are raised in modern goose ranches as well as traditional goose ranches in Turkey. However, it is stated that the number of mast geese in Turkey has been decreasing recently. The most important reason for this situation is the low breeding of goose from Turkey and the slaughter of the existing ones in slaughterhouses. Thus, there is no breeding in the provinces other than the provinces with goose production due to the lack of the integrated facility. The lack of integrated goose facilities has posed an obstacle to the processing of goose meat and its introduction to market shelves. This circumstance draws the line at recognising the goose sufficiently by the Turkish people (Diken, 2022).

Tomography, combining two different words Tomos and graphic, is a radiological imaging method that examines the cross-sectional image of an object through parallelised X-rays (Capello & Cauduro, 2008). Similarly, cross-sectional images are captured by rotating the detector and X-ray tube around the object in computed tomography (Adapınar, 2016).

In the late 20th century, the three-dimensional modelling technique, which has been increasingly utilised in industry, has recently become one of the most preferred methods in the field of medicine (D'Ursoet *et al.,* 1999). The 3D imaging of tissue and organ parts is called as "reconstruction". These reconstructive images help us to establish treatment protocols in clinical cases, complicated pathological cases, and forensic cases that require re-identification procedures. They also contribute to some anthropological studies. The reconstruction technique is also important in the field of anatomy as it simplifies the comprehension of irregular

structures and provides educational materials (Verhoff *et al.,* 2008; Sarıtaş, 2015).

Three-dimensional reconstruction studies are increasing with the developing technology. Researchers have carried out these studies in different animal species (İnce *et al.,* 2018; Demircioglu & Gezer İnce, 2020; Demircioglu *et al.,* 2020; Demircioglu *et al.,* 2021; Yılmaz & Demircioglu, 2021a; Yılmaz & Demircioglu, 2021b).

This study presents a detailed anatomical description of structure of the thoracic and pelvic limb bones of German Mast geese. For this purpose, a 3D modelling was made through an MDCT imaging device. On the other hand, a comparison of the osteometric and volumetric values of the long bones between sexes was aimed. In conclusion, it is expected that the 3D models can be utilised in some scientific fields such as anatomy, surgery and archaeozoology, as well as can also contribute to the classification of species and provide data for forensic science studies.

MATERIALS AND METHODS

In this study, ten (five females and five males) dead geese were used. These geese were collected from German mast goose breeders in Elazığ province. They had no infectious diseases or anomaly risks. Before the study, an ethical form was taken with the decision numbered 2020/14 from the Animal Experiments Local Ethics Committee of Fırat University. Nomina Anatomica Veterinaria (2017) was used for the nomenclature of the structures in this study.

Capturing and modelling of computed tomography images

MDCT images of the anterior and posterior extremities of the German mast goose – the main material of this study – were obtained with a 64-slice, multi-detector, spiral computed tomography device (General Electronic Revolution) at 80 KV, 200 MA, and a 639 mGY. A 0.625 mm thick section was taken(Prokop, 2003). MDCT images were converted to DICOM format for modelling. The collected data were transferred to 3D Slicer (5.0.2) capable of 3D modelling. The threshold value was first determined to emphasise the osteological structures. All bones were segmented by creating different masks for the selected bone tissue with the "Regional magnification" command and converted into 3D forms with the "Calculate 3D" command. These 3D forms were osteometrically measured based on the reference points that were suggested by Von den Driesch (1976).

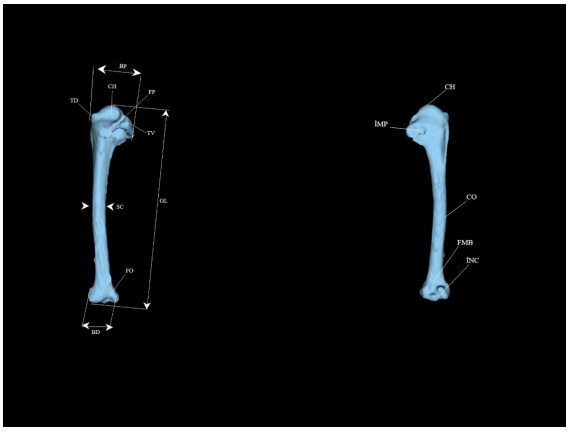

Figure 1 – Anatomical structures and osteometric measurement points of humerus bone of German mast goose.

Td: Tuberculum dorsale, Fp: Fossa pneumotricipitalis, Ch: Caput humeri, Co: Corpus humeri, Ic: Incisura capitis, Tv: Tuberculum ventrale, Fo: Fossa olecrani, Imp: Impressio coracobrachialis, Inc: Incisura intercondylaris, Fmb: Fossa m.brachialis, GL: Greatest length, Bp: Breadth of the proximal end from the Tuberculum laterale or dorsale to the Tuberculum mediale or ventrale, SC: Smallest breadth of the corpus , Bd: (Greatest) breadth of the distal end.

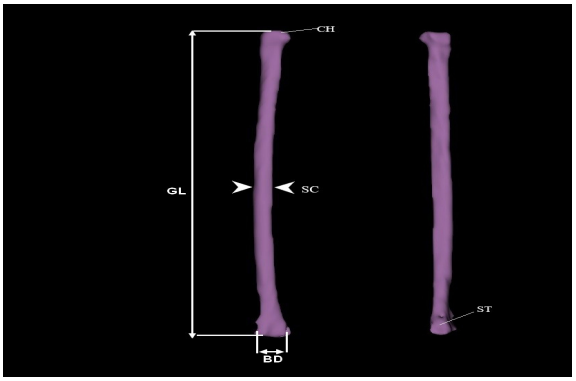

Figure 2 – Anatomical structures and osteometric measurement points of the Radius bone of the German mast goose.

Ch: Cotylahumeralis, St: Sulcus tendinosus, GL: Greatest length, SC: Smallest breadth of the corpus, Bd: breadth of the distal end.

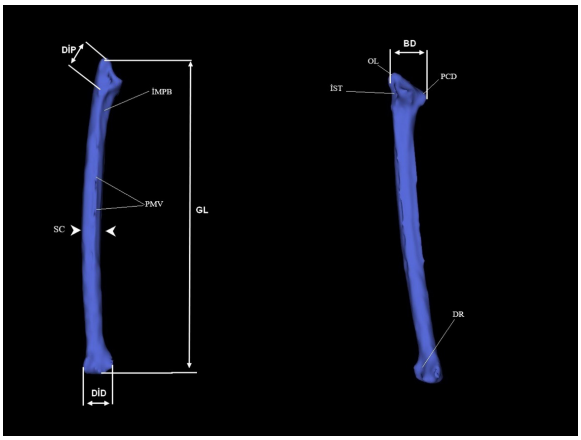

Figure 3 – Anatomical structures and osteometric measurement points of the ulna bone of the German mast goose.

Impb: Impressio m. brachialis, Pmv: Papillae remigales ventrales, Ol: Olecranon, İst: İmpressio m.scapulotricipitis, DR: Depressio radialis. GL: Greatest length, DİP: Diagonal of the proximal end from the caudal border of the Olecranon to the cranial border of the Facies articularis lateralis or dorsalis, BP: (Greatest) breadth of the proximal end from the Facies articularis medialis or ventralis to the Facies articularis lateralis or dorsalis, SC: Smallest breadth of the corpus, DİD: Diagonal of the distal end.

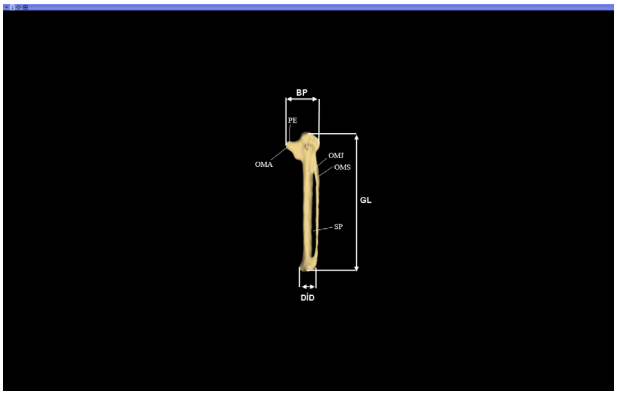

Figure 4 – Anatomical structures and osteometric measurement points of the carpometacarpus bone of the German mast goose.

Pe: Proc.extensorius, Oma: Os metacarpalealulare, Omj: Os metacarpalemajus, Oms: Os metacarpale minus, Sp: Spatium intermetacarpale, GL: Greatest length,BP: (Greatest) breadth of the proximal extremity, DID: Diagonal of the distal end.

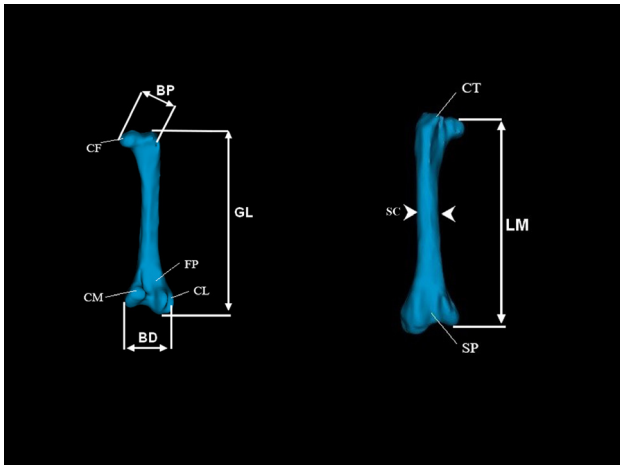

Figure 5 – Anatomical structures and osteometric measurement points of the femur bone of the German mast goose.

CF: Caput femoris, CT: Trochanter femoris, CM: Condylus medialis, CL: Condylus lateralis, SP: Sulcus intercondylaris, GL: Greatest length, BP: (Greatest) breadth of the proximal extremity, BD: breadth of the distal end, LM: medial length. SC: Smallest breadth of the corpus

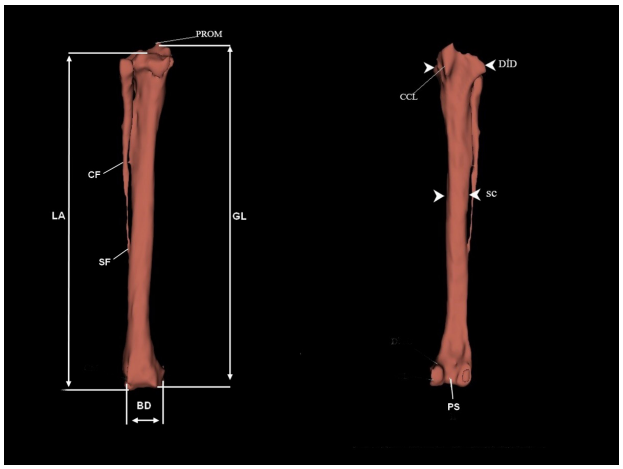

Figure 6 – Anatomical structures and osteometric measurement points of the tibiotarsus bone of the German mast goose.

PROM: proc. cnemialis, CCL: Crista cnemialis lateralis, CF: Corpus fibula, SF: Spina Fibula, PS: Pons supratendineus, GL: Greatest length, BD: breadth of the distal end, LA: Axial length, DID: Diagonal of the distal end, SC: Smallest breadth of the corpus.

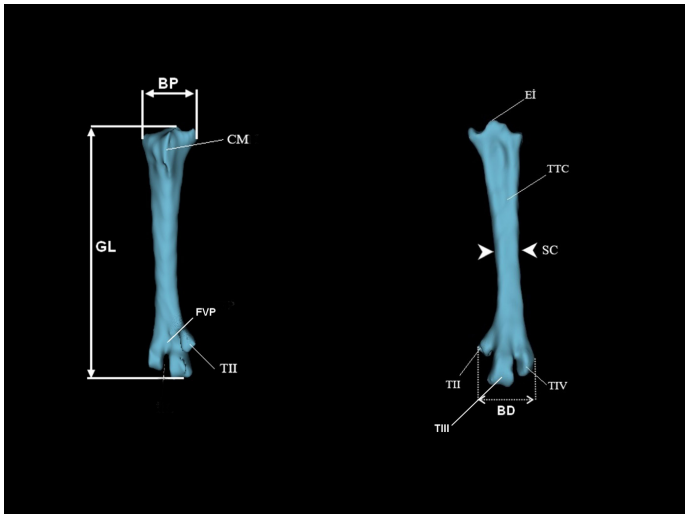

Figure 7 – Anatomical structures and osteometric measurement points of the tarsometatarsus bone of the German mast goose.

EI: Eminentia intercondylaris, CM: Crista medianoplantaris, TTC: tuberositas m.tibialis cranialis, FVP: Foramen vasculare distale, TII: Os trochlea metatarsi II, TIII: Os trochlea metatarsi III, TIV: Os trochlea metatarsi IV, GL: Greatest length, BP: (Greatest) breadth of the proximal extremity, SC: Smallest breadth of the corpus.

Statistical Analysis

SPSS 22.0 program was used for statistical analysis of morphometric measurements. Kolmogorov-Smirnov and Shapiro-Wilk tests were used to determine whether the measurement values were parametric or non-parametric. An independent sample test was performed for comparisons between our results and the Genders.

RESULTS

Macro-anatomical results

Humerus

The macro-anatomical examination of the humerus bone of the German mast goose revealed an ellipsoid head. Tuberculum dorsale and tuberculum ventrale were observed. A pit called as fossa pneumotricipitalis was observed in the caudal part of the humerus. When the distal part of the humerus was examined, the condylus ventralis and condylus dorsalis were prominent. Condylus dorsalis was above the condylus ventralis. Epicondylus ventralis et dorsalis was observed just above the condylus.

Radius and Ulna

As in mammals, the ulna and radius form the skeleton of the antebrachium in birds. The ulna is slightly longer than the radius. The proximal end of the ulna forms a joint with the humerus. The olecranon at the proximal end of the ulna was observed to have a weak structure.

Carpometacarpus

They were called as carpometacarpus with the combination of os carpi and os metacarpale bones.

Femur

It was observed that the femur – the first of the posterior limb bones – was slightly inclined towards the cranial. The head of the femur (caput ossis femoris) exceeded the level of the lateral trochanter. Condylus lateralis et medialis was observed in the distal part of the femur. Epicondylus lateralis et medialis were observed lateral to both condyli.

Tibiotarsus

More than one crista was observed in the proximal part of the tibiotarsus bone. These are called as crista patellaris and crista cnemialis lateralis. It was observed that there were sulci between the crista. Although the proximal part was triangular, it was transformed into a cylindrical structure towards the distal part. The epicondylus lateralis et medialis were prominent in the distal part.

Tarsometatarsus

There is no separate tarsus bone in birds. The tarsus bone forms the tarsometatarsus as well as the metatarsus. It was also observed to be attached in German mast geese. A protrusion called as hypotarsus was observed on the distal part of the tarsometatarsus. There were cristae hypotarsi and sulci hypotarsi around the hypotarsus.

Statistical results

Tables 1, 2, 3, 4, 4, 5, 6 and 7 show the statistical findings obtained from the German mast geese for measurement values, volume and surface area. It was determined that male geese were bigger than female geese in German mast geese. It was observed that males were longer than females in the parameter GL in all measured bones. In the humerus bone, the parameter Bd and surface area were statistically significant ($p<0.05$). In the radius bone, the parameter GL was statistically significant ($p<0.05$). The volumes of the radius and carpometacarpus bones were highly significant ($p<0.01$). Di-prox and surface area of the ulna bone were statistically significant ($p<0.05$). When the dip-dis parameter was analysed, it was observed to be highly significant ($p<0.01$). When the measurement points of the femur bone were analysed, statistical significance was found in LM, BP, SC and volume parameters ($p<0.05$). The parameter Dp was highly significant ($p<0.01$). In the tibiatarsus bone, the parameters LA and SC were highly significant ($p<0.01$). When the parameter Bd was analysed, it was determined to be statistically significant ($p<0.05$). In the tarsometatarsus bone, the surface area parameter was statistically significant ($p<0.05$).

Table 1 – Osteometric measurements of the humerus bone of the German mast goose.

Parameter	Sex	N	Mean	St-d.	*p*
Gl	Male	5	166.58	1.92	0.120
	Female	5	164.79	1.06	
Bp	Male	5	37.64	1.05	0.157
	Female	5	35.32	.60	
Sc	Male	5	10.76	.33	0.151
	Female	5	10.25	.20	
BD	Male	5	25.38	1.54	0.032
	Female	5	25.15	.661	
Volume (cm^3)	Male	5	7.45	2.12	0.55
	Female	5	7.21	1.18	
Surface area (cm^2)	Male	5	6.58	1.16	0.42
	Female	5	6.02	1.15	

Table 2 – Osteometric measurements of the radius bone of the German mast goose.

Parameter	Sex	N	Mean	St-d.	*p*
Gl	Male	5	143.82	2.05	0.012
	Female	5	143.69	0.67	
Sc	Male	5	6.51	0.36	0.170
	Female	5	6.39	0.14	
Bd	Male	5	9.58	0.76	0.217
	Female	5	9.00	0.53	
Volume(cm^3)	Male	5	5.89	0.52	0.02
	Female	5	5.25	0.23	
Surface area (cm^2)	Male	5	4.12	0.11	0.56
	Female	5	4.01	0.36	

Table 3 – Osteometric measurements of the ulna bone of the German mast goose.

Parameter	Sex	N	Mean	St-d.	*p*
GL	Male	5	153.22	2.88	0.057
	Female	5	152.22	1.22	
DİP	Male	5	23.3061	1.64	0.044
	Female	5	21.30	.15	
BP	Male	5	18.29	3.25	0.054
	Female	5	17.19	0.21	
DİD	Male	5	15.07	.71	0.003
	Female	5	14.88	.31	
SC	Male	5	8.62	.26	0.229
	Female	5	8.56	.19	
Volume (cm^3)	Male	5	5.02	.10	0.089
	Female	5	4.75	.02	
Surface area(cm^2)	Male	5	4.55	.55	0.23
	Female	5	4.12	.21	

Table 4 – Osteometric measurements of the carpometacarpus bone of the German mast goose.

Parameter	Sex	N	Mean	St-d.	*p*
GL	Male	5	90.90	2.19217	.840
	Female	5	89.47	2.02378	
BP	Male	5	22.85	2.19042	.565
	Female	5	22.35	1.61908	
DID	Male	5	14.24	.70034	.803
	Female	5	13.24	.62683	
Volume(cm^3)	Male	5	3.55	.25	.002
	Female	5	3.28	.12	
Surface area (cm^2)	Male	5	3.12	.02	.056
	Female	5	3.01	.06	

Table 5 – Osteometric measurements of the femur bone of the German mast goose.

Parameter	Sex	N	Mean	St-d.	*p*
GL	Male	5	88.11	4.59	.062
	Female	5	86.11	1.84	
LM	Male	5	83.46	4.28	.031
	Female	5	83.38	1.44	
BP	Male	5	22.41	2.53	.016
	Female	5	21.84	.75	
DP	Male	5	13.44	1.73	.002
	Female	5	12.92	.35	
SC	Male	5	8.63	1.04	.032
	Female	5	7.94	.36	
BD	Male	5	23.75	1.00	.836
	Female	5	23.70	1.11	
DD	Male	5	14.09	1.31	.090
	Female	5	14.14	.41	
Volume(cm^3)	Male	5	7.12	1.15	0.42
	Female	5	6.89	1.02	
Surface area (cm^2)	Male	5	6.85	.14	.156
	Female	5	6.14	.18	

Table 6 – Osteometric measurements of the tibiotarsusbone of the German mast goose.

Parameter	Sex	N	Mean	St-d.	*p*
GL	Male	5	154.09	3.85	.078
	Female	5	153.80	2.08	
LA	Male	5	154.01	8.28	.008
	Female	5	149.17	2.39	
DIP	Male	5	16.53	.94	.084
	Female	5	15.58	.55	
SC	Male	5	8.04	.56	.002
	Female	5	7.42	.12	
BD	Male	5	18.35	1,01	.010
	Female	5	17.63	.13	
DD	Male	5	11.2520	.70	.100
	Female	5	11.6580	.36	
Volume (cm^3)	Male	5	6.12	.07	.085
	Female	5	5.98	.12	
Surface area (cm^2)	Male	5	5.75	.18	.185
	Female	5	5.12	.11	

Table 7 – Osteometric measurements of the tibiotarsusbone of tarsometatarsus the German mast goose.

Parameter	Sex	N	Mean	St-d.	*p*
GL	Male	5	89.73	2.61	.203
	Female	5	88.39	.85	
SC	Male	5	7.72	.43	.095
	Female	5	7.64	.24	
BD	Male	5	18.46	1.09	.050
	Female	5	18.70	.17	
BP	Male	5	18.62	.39	.454
	Female	5	18.69	.21	
Volume (cm^3)	Male	5	3.89	.19	.102
	Female	5	3.12	.25	
Surface area (cm^2)	Male	5	3.55	.12	.025
	Female	5	3.05	.16	

DISCUSSION AND CONCLUSION

This is the first time that 3D models of the thoracic and pelvic limbs of German mast geese have been produced from computed tomography images in a study. The ossa membri thoracici and pelvini bones of German mast geese were analysed morphologically and morphometrically using these models.

According to Gilbert *et al.* (1996), the mean measures of long bones in Canadian geese were calculated as 81.5 mm for the femur, 150.5 mm for the tibiotarsus and 172.5 mm for the humerus, while these measurements were 88.1 mm, 154.09 mm and 166.58 mm, respectively, in German mast geese.

The study by Ehrlich *et al.* (2022) revealed that while the greylag goose and the domestic goose were distinguished from other modern species based on coracoid and tarsometatarsus measurements, some archaeological specimens clustered with the domestic goose and some with the greylag goose. This may suggest that both coracoid and tarsometatarsus are useful skeletal elements to distinguish goose species. Therefore, the morphometric examination of the bones of German mast geese in the present study is highly important for the recognition of this goose species.

Kırbas Doğan & Takcı (2021) reported that the BD measurement parameter in the humerus bone was statistically quite significant as 27.91 ± 0.40mm in males and 25.56 ± 0.33mm in females in their studies in geese in the Kars region. In our study on German mast geese, the BD parameter was found to be statistically significant at 25.38±1.54mm in males and 25.15±0.66mm in females ($p<0.05$). Kırbas Doğan & Takcı (2021) reported the Radius bone GL measurement parameter of geese in the Kars region as 154.20±1.63mm in males and 169.75±1.31mm in males. When the GL measurement point of German

mast geese was examined, it was found to be statistically significant at 143.82±2.05mm in males and 143.69±0.67mm in females (p<0.05). When the femur bone of the geese in the Kars region was examined, the LM measurement parameter was reported as 88.36±1.01mm in males and 82.26±0.87mm in females. In our study, the LM parameter was found to be 83.46±4.28mm in males and 83.38±1.38mm in females (p<0.05).

Basoğul & Beşoluk (2016) reported the tibiotarsus bone to be 8.10±0.40mm in rock partridge and 9.84±0.43mm in pheasant, tarsometatarsus bone as 4.69±0.27mm in rock partridge and 6.38±0.19mm in pheasant. When the German mast geese were examined, it was seen that the measurements were larger than both wing bones.

Rajani *et al.,* (2018) reported the length of the femur as 300.8±0.5mm, 90.9±0.3mm, and 60.5±0.2mm, respectively, in their study in ostrich, domestic poultry, and ducks. In German mast geese, we determined it as 88.11±4.59mm in males and 86.11±1.84mm in females. It was seen that the German mast geese were smaller than the ostrich, close to the other species, and larger. They reported the tarsometatarso bone as 440.8 ± 0.4 mm in ostriches, 80.8 ± 0.2 mm in domestic poultry, and 60.2 ± 0.2 mm in ducks. In German mast geese, tarsometatarsus was found to be 89.73±2.61mm in males and 88.39±0.85mm in females.

İlgün *et al.,* (2019) measured the average length of the femur as 112.5mm in their study on crested pelicans and measured the mean tibiotarsus bone as 185mm in crested pelicans. They found that the tibiotarsus bone of the crested wormwood was larger than the femur. In our study on German mast accidents, it was determined that the bones of the femur and tibiotarsus were smaller than the crested pelicans, and the bone of the tibiotarsus was larger than the femur, as in the crested pelicans.

Although the femur is generally considered to be the longest bone of the skeletal system (Dursun, 2006; Bahadır & Yıldız, 2016; Islam, Singh, & Guatam, 2018), the GL measurement of the humerus bone was found to be longer in this study.

Dursun (2002) reported that the length of the tibia was twice as long as the femur in waterfowl, while in pigeons and chickens, the tibia was only one-third as long as the femur. In German mast geese, the greatest length of the tibia was found to be almost twice as long as the greatest length of the femur.

Coulson *et al.* (1983) investigated the correlations of some morphometric measurements on sex in Herring Gull and found that the measurements in females were lower than those in males. The present study also revealed that all measurements were lower in females.

Another study on gulls (Pokines 2022) measured the humerus, ulna, radius, and tibiotarsus of chickens as 85 mm, 76 mm, 61 mm, and 89 mm, respectively, and the length of the ulna in turkeys as 153 mm. It was observed that German mast goose measurements were compatible with turkeys.

Consequently, this study would be helpful to develop a reliable methodology to differentiate German mast geese from other goose species. No findings are available in the literature on the use of the CT technique in the morphometric and morphological analysis of the thoracic and pelvic limbs of German mast geese. Therefore, we believe that the findings of the present study would be useful as a main data set.

AUTHORS' CONTRIBUTION

BCG and BB conceived and designed the research. BCG and BB performed the material preparation and experiments. BCG and BB performed the data collection and analysis. BCG and BB drafted the manuscript. All authors read and approved the final manuscript.

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CONFLICT OF INTEREST

The authors declared that there is no conflict of interest.

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