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Three-Dimensional Examination of Humerus and Antebrachium Bones in the Red hawk (*Buteo Rufinus*) with Computed tomography (CT)

Veysel DELİBAŞ[1,*] Zafer SOYGÜDER[1] Cemil GÖYA[2] Loğman ASLAN[3] Gamze ÇAKMAK[1]

[1]Van Yuzuncu Yil University, Faculty of Veterinary Medicine, Department of Anatomy, 65040, Van, Türkiye
[2]Van Yuzuncu Yil University, Faculty of Medicine, Department of Radiodiagnostic, 65040, Van, Türkiye
[3]Van Yuzuncu Yil University, Faculty of Veterinary Medicine, Department of Surgery, 65040, Van, Türkiye

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ABSTRACT The red hawk (*Buteo Rufinus*) is a medium-sized bird of prey with wide wings, belonging to the order Falconiformes and a member of the Accipitridae family. The Red hawk is a wild bird species and is easily recognized by its black feathers and red color on its wing feathers. In poultry, the thoracic extremity is developed as a wing. Techniques such as radiography, computed tomography and magnetic resonance contribute significantly to the evaluation of biological data in endangered species and wildlife because they provide the best view of anatomical structures and organs, are non-invasive, and allow sensitive diagnoses. The aim of this study was to create 3D models of the humerus and antebrachium bones of the Red hawk, an important bird of prey, with multi-detector computer tomography and to examine the bones mentioned morphologically and morphometrically through the models obtained. Humerus and antebrachium bones of a total of 6 dead adult Red hawks, 3 females and 3 males, were used as materials. When the morphometric results were examined, the average humerus length, average ulna length and average radius length in Red hawks were expressed in mm for the left and right extremities, regardless of gender. Moreover morphometric measurements of the humerus, ulna and radius bones were compared statistically between the right and left wings, and it was concluded that there was a significant difference between some values with a value of p<0.05.

Keywords: *Computed tomography, Red hawk, Humerus, Radius, Ulna.*

ÖZ

Kızıl Şahinde (*Buteo Rufinus*) Humerus ve Antebrachium Kemiklerinin Bilgisayarlı tomografi (BT) ile Üç Boyutlu Olarak İncelenmesi

Kızıl şahin *(Buteo Rufinus)* Falconiformes takımında yer alan ve Accipitridae familyasının bir üyesi olarak bulunan orta boylu geniş kanatlara sahip bir yırtıcı kuştur. Kızıl şahin yabani bir kanatlı türü olup kanat teleklerindeki siyah renkli tüyleri ve kızıl rengiyle kolayca tanınmaktadır. Kanatlılarda ön veya torakal extremite kanat halinde gelişmiştir. Kanat (Ossa membri thoracicci) ise sırasıyla scapula, clavicula, os coracoides, humerus, antebrachium (ulna ve radius), carpus, metecarpus ve digiti'den meydana gelmektedir. Radyografi, bilgisayarlı tomografi ve manyetik rezonans gibi teknikler, anatomik yapıların ve organların en iyi görünümünü sağlamaları, invaziv olmamaları ve hassas teşhislere imkan vermeleri nedeniyle nesli tükenmekte olan türlerin ve yaban hayatında biyolojik verilerin değerlendirilmesine önemli derecede katkı sağlamaktadır. Bu çalışma ile önemli bir yırtıcı kuş olan Kızıl şahinin humerus ve antebrachium kemiklerinin multi dedektörlü bilgisayarlı tomografi ile 3D modellerini oluşturmak, ayrıca elde edilen modeller aracılığı ile belirtilen kemiklerin morfolojik ve morfometrik olarak incelenmesi amaçlanmıştır. Materiyal olarak 3 adet dişi ve 3 adet erkek olmak üzere toplam 6 adet ölmüş erişkin Kızıl şahin'e ait humerus ve antebrachium kemikleri kullanıldı. Morfolojik olarak sonuçlar incelendiğinde, bilgisayarlı tomografi ile elde edilen 3 boyutlu görüntülerin anatomik yapıları net bir şekilde ortaya koyduğu sonucuna varılmıştr. Morfometrik sonuçlar incelendiğinde Kızıl şahinlerde ortalama humerus uzunluğu, ortlama ulna uzunluğu ve ortalama radius uzunluğu cinsiyet ayrımı yapmaksızın sol ve sağ extremite için mm şeklinde belirtilmiştir. Ayrıca humerus, ulna ve radius kemiklerinin morfometrik ölçümleri sağ ve sol kanat arasında istatistiksel olarak karşılaştırılmış ve bazı değerler arasında p<0.05 değeri ile anlamlı bir farklılık olduğu sonucuna varılmıştır.

Anahtar Kelimeler: *Bilgisayarlı tomografi, Humerus, Kızıl şahin, Radius, Ulna.*

✉ *Corresponding author: veyseldelibas@hotmail.com

INTRODUCTION

A member of the order Falconiformes and a member of the family Accipitridae, the Red hawk, is a medium-sized bird of prey with broad wings (Orhan et al. 2002). The Red hawk is a wild bird species and is easily identified by its black feathers and red wing feathers. It can to fly particularly fast is due to its morphologically well-developed wings (Demirsoy 1992). For this reason, it is the bird species with the best maneuverability among birds of prey. In addition, the main characteristics of Red hawks are the presence of a sharp, well-developed upper jaw, a hook-shaped beak that widens downwards, and very strong spurs (Demirsoy 1992).

In birds, the wing develops as a thoracic extremity. The wing is connected to the body by a belt consisting of three bones called ossa cinguli extremitatum thoracicarum (scapula, clavicula and os coracoideus) (Gültekin 1974; Dursun 2008). Ossa membri thoracici consists of scapula, clavicula, os coracoideus, humerus, antebrachium (ulna and radius), carpus, metecarpus and digiti, respectively. An important feature that distinguishes Red hawks from other bird species is their wide wingspan (Gültekin 1974; Dursun 2008). For this reason, a significant part of the stated wingspan consists of the long bones (humerus and antebrachium) that form the wing structure of this bird species.

Humerus: It is one of the long bones participating in the wing structure. Since it is a long bone, it has a body consist the trunk and two ends, proximal and distal (Gültekin 1974; Dursun 2008). Antebrachium: This bone, consisting of ulna and radius, is examined in three regiones, just like the humerus. From these regione, the proximal end is positioned backwards, the distal end is positioned forward, and the bone body is positioned parallel to the humerus (Gültekin 1974; Dursun 2008).

Today, computer and 3D reconstruction technologies, widely used in the medical field, are also rapidly gaining ground in veterinary medicine. It is more useful than other anatomical methods because it clearly details the complex structure of the tissue to be imaged, especially through images obtained by multidetector computed tomography (MDCT) and magnetic resonance imaging (MRI), which are radiological imaging techniques. Considering the results of many studies, it can be said that radiological imaging techniques create versatile images of tissues and organs and that a three-dimensional model of any tissue can be created using these images (D'Urso et al. 1999; Verhoff et al. 2008; Demircioğlu et al. 2020).

In the literature review, it was determined that fractures in birds of prey mostly occur in the wings and less frequently in the foot and spinal skeleton (Kibar and Bumin 2006; Aslan et al. 2009). In line with the studies conducted in this context, it has been reported that 53% of the fractures in the wings occur in the humerus and 47% in the radius-ulna (antebrahium) bones (Kibar and Bumin 2006). Hence, many studies have been done on humerus and antebrachium in poultry; chicken, domestic duck, pigeon and quail (Yıldız et al. 1998), Turkey vulture (Novitskaya et al. 2017), Griffon vulture and Greater flamingo (Frongia et al 2021), Japanese quail (Demiraslan et al. 2014), Kars goose (Doğan and Takçı 2021), Herring gull (*Larus argentatus*, Pontoppidan), Rock pigeon (Columba livia Gmelin) and Willow ptarmigan (*Lagopus lagopus*/Linnaeus) (Bonser 1995), Blue canary (Bhargavi et al. 2017), Commercial broiler and Desi chicken (Vistro et al. 2015). Especially considering this situation, it is important to examine the humerus and antebrachium bones in birds of prey from an anatomical perspective using radiological imaging techniques. In this study, three-dimensional examination of humerus and antebrachium bones in the Red hawks (*Buteo Rufinus*) with computed tomography (CT) was studied to examine the specified bones morphologically and morphometrically through the models obtained.

MATERIAL AND METHODS

Animals

This study was carried out with the decision of Van Yuzuncu Yil University Animal Experiments Local Ethics Committee dated 30/06/2022 and numbered 2022/06-03. In the study, the humerus and antebrachium bones were used of a total of 6 dead adult Red hawks (3 females and 3 males) brought to Van Yuzuncu Yil University Wild Animals Protection and Rehabilitation Center at different times by The Nature Conservation and National Parks Van.

CT and 3D Modeling Process

The bones used in the study were scanned with a 256-slice computer tomography device (Philips Brilliance Ict). MDCT device with reference to Prokop (Prokop 2003) for computed tomography scanning; It was set as 80 kV, 200 MA, 639 mGY and cross-sectional thickness of 0.625 mm. The scanned images were saved as DICOM and transferred to the medical image processing program MIMICS 21.0 (The Materialize Group, Leuven, Belgium) for 3D modeling.

Process of Obtaining Morphometric Measurements from 3D Images

Nomina Anatomica Avium (Baumel and Club 1993) was taken as reference in morphological analyzes and in the use of all anatomical words within the scope of the study. Additionally, Von Den Driecsh (Von Den Driesch 1976) and Atalar et al. (Atalar et al. 2007) were used as references in determining morphometric measurement points. The obtained 3D models and the morphometric measurement points taken are given in Figures 1, 2 and 3.

Measurement parameters of humerus bone:

GL: Length of the humerus bone; SC: The smallest corpus width of the humerus bone; Bp: Proximal width of the humerus; Bd: Distal width of the humerus.

Measurement parameters of ulna bone:

UGL: Length of the ulna bone; USC: The smallest corpus width of the ulna bone; UBp: Proximal width of Ulna; UBd: Distal width of ulna.

Measurement parameters of radius bone:

RGL: Length of radius bone; RSC: The smallest corpus width of the radius bone; RBp: Proximal width of the radius; RBd: Distal width of radius.

Statistical Analysis

As descriptive statistics; average, standard deviation, minimum and maximum values are expressed. While the Mann-Whitney U test was used to compare whether there were differences between genders for these characteristics, the Wilcoxon test was used to compare the Right-Left differences. In the calculations, the statistical significance level was taken as 5% and the SPSS (21.0 ver.) statistical package program was used.

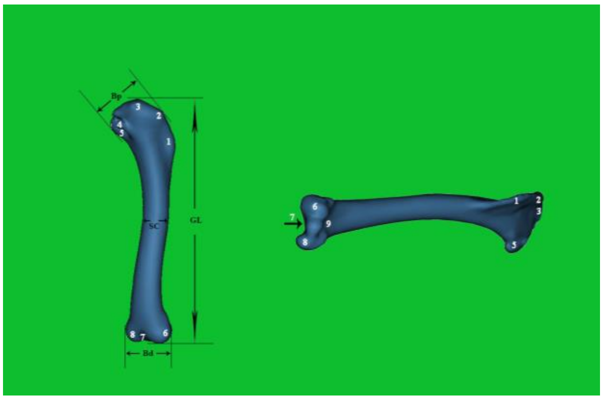

Figure 1: Anatomical points of the humerus; 1: crista deltopectoralis, 2: tuberculum dorsale, 3: caput humeri, 4: foramen pneumotricipitalis, 5: tuberculum ventrale, 6 condylus dorsale, 7: fossa olecrani, 8: condylus ventralis. Morphometric measurements of the humerus; GL: Length of the humerus bone, SC: The smallest corpus width of the humerus bone, Bp: Proximal width of the humerus, Bd: Distal width of the humerus.

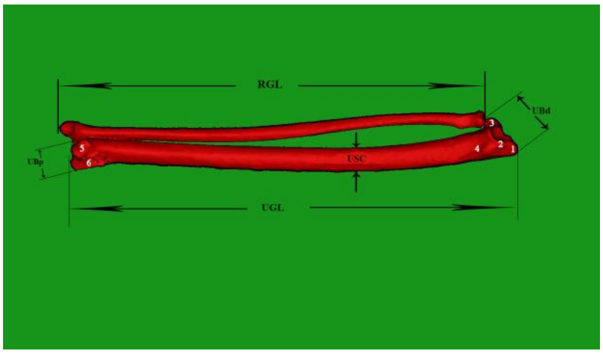

Figure 2: Anatomical points of the ulna; 1: olecranon, 2: crista intercotylaris, 3: cotyla dorsalia, 4: impressio brachialis, 5: incisura tuberculum carpale, 6: sulcus intercondylaris. Morphometric measurements of the ulna; UGL: Length of the ulna bone, USC: The smallest corpus width of the ulna bone, UBp: Proximal width of ulna, UBd: Distal width of ulna.

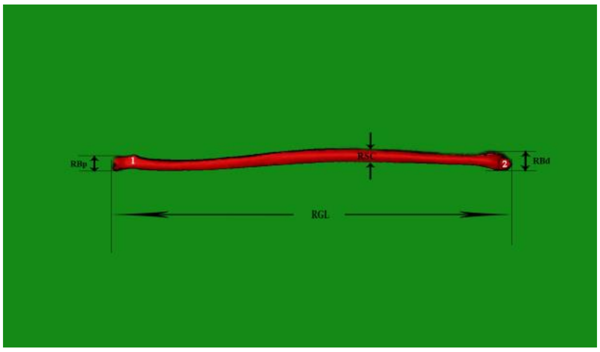

Figure 3: Anatomical points of radius; 1: tuber bicipitalis radialis, 2: sulcus tendinosa. Morphometric measurements of radius; RGL: Length of radius bone, RSC: The smallest corpus width of the radius bone, RBp: Proximal width of the radius. RBd: Distal width of radius.

RESULTS

Morphological Findings: When the 3D model of the humerus bone was examined morphologically, it was determined that all anatomical formations on the bone could be clearly seen. In this context, when the cranial surface of the humerus was examined, the caput humeri was clearly seen first in the proximal end. The presence of tuberculum dorsale was detected just above this anatomical structure, and tuberculum ventrale was detected below it. In addition, the crista deltopectoralis, which extends along the dorsal edge of the body of the humerus, is one of the important structures seen. When the caudal face is examined; In addition to the structures on the cranial face, there is the foramen pneumotricipitalis, which is very clearly visible. The tuberculum ventrale was clearly seen just lateral to the before mentioned hole. Due to straight the body of the humerus, it does not show any anatomical features.

Similarly, when the extremitas distalis of the humerus is examined, condylus dorsalis and ventralis are clearly seen on the cranial face. Additionally, there is fossa olacrani between the two condyles mentioned on this face. When the caudal face is examined, the presence of a shallow depression (fossa musculus brachialis) that allows the radius to articulate is seen.

Antebrachium: It consists of two bones (radius and ulna) parallel to the humerus, with the proximal end facing backward and the distal end facing forward. It was observed that it was located lateral to the ulna bone and had a body approximately twice as thick as the radius. The radius and ulna bones are tightly connected to each other, creating a wide spatium between them. When the proximal part of the ulna is examined; olecranon, crista intercotylaris, cotyla dorsalia and impressionio brachialis were clearly seen. Distal to the ulna are the incisura tuberculum carpae and sulcus interconylaris, which serve to articulate with the carpal bones.

The radius articulates proximally with the humerus and ulna. In this region, the tuber bicipitalis radialis protrusion can be seen just below the caput radiale. The distal part of the radius is tightly connected with the ulna, which is located in the proximal part. On the lateral side of the distal region there is a groove called the sulcus tendinosa.

Morphometric Findings: According to morphometric results of the humerus, the average left and right humerus lengths (GL) in Red hawks that don't have gender identification were 125.11 mm and 126.17 mm, respectively, and the smallest corpus widths of the left and right humerus were 9.83 mm and 10.07 mm.

In addition, it was concluded that the proximal extremities width of the humerus of the left and right was 28.51 mm and 29.34 mm, respectively, and the distal extremities width of the humerus of the left and right was 21.61 mm and 20.99 mm, respectively (Table 1). When all left and right humerus morphometric measurement results were compared between male and female genders, it was determined that there was no difference in terms of gender with a $p>0.05$ value (Table 1).

In the morphometric examination of the ulna, it was observed that the left and right average GL values were 140.01 mm and 139.89 mm, respectively, and the SC value was 8.12 mm and 7.15 mm. In addition to these measurements, it was concluded that the Bp values of the left and right ulna were 10.23 mm and 10.21 mm, respectively, and the Bd values of the left and right ulna were 15.66 mm and 15.10 mm, respectively. According to the statistical results, it was observed that all right and left measurement parameters of the ulna did not show a significant difference between male and female genders with a value of p>0.05 (Table 1).

In the morphometric examination of the radius, the average left and right GL values were 128.54 mm and 129.37 mm, respectively, the average left and right SC values were 5.12 mm and 5.06 mm, the average left and right Bp values were 10.12 mm and 10.21 mm respectively determined. Additionally, left and right Bd values were 9.03 mm and 8.30 mm. It was revealed statistically (p>0.05) that there was no difference between male and female genders in all right and left measurement parameters, as in the humerus and ulna bones (Table 1).

In addition, morphometric left or right-sided variations of the humerus, ulna and radius bones were examined in Red hawks, separately in male and female genders. In this context, Bp and GL measurement parameters of the humerus in tercel showed a positive difference on the right side with a value of p=0.003 (Table 2). Similarly, when the ulna was examined, the Bd and SC measurement parameters of the ulna in tercel showed a positive difference on the left side, with values of p=0.016 and p=0.001, respectively (Table 2). When the Bd and GL measurement parameters of the radius in males were examined, it was determined that the Bd measurement showed a positive difference in the left direction with the value of p=0.003 and the GL measurement showed a positive difference in the right direction with the value of p=0.021 (Table 2).

When all measurement parameters of the humerus, ulna and radius were compared in the right/left direction in terms of female gender, all measurement parameters of the humerus and radius did not show any difference with a p>0.05 value (Table 2). However, contrary to the stated situation, it was determined that the ulna showed a positive difference in the left direction only with the SC measurement parameter p=0.018 (Table 2).

Table 1: Statistical examination of gender characteristics of measurement subjects of humerus, ulna and radius bones.

		Humerus			Ulna			Radius		
	Gender	Mean value	Standard deviation	p-value	Mean value	Standard deviation	p-value	Mean value	Standard deviation	p-value
Left Bp	Male	28.61	.452	0.493	10.25	.559	0.918	10.14	.511	0.924
	Female	28.29	.601		10.20	.233		10.10	.197	
	Generally	28.51	.472		10.23	.446		10.12	.406	
Left Bd	Male	21.70	.393	0.781	15.75	.726	0.662	9.05	.325	0.839
	Female	21.43	.523		15.48	.452		8.99	.162	
	Generally	21.61	.409		15.66	.614		9.03	.263	
Left GL	Male	125.15	.295	0.796	140.24	.502	0.138	128.44	.426	0.401
	Female	125.03	.862		139.55	.028		128.74	.035	
	Generally	125.11	.452		140.01	.530		128.54	.364	
Left SC	Male	9.73	.491	0.498	8.04	.530	0.580	5.14	.329	0.828
	Female	10.02	.212		8.28	.063		5.09	.042	
	Generally	9.83	.418		8.12	.429		5.12	.257	
Right Bp	Male	29.57	.436	0.102	10.78	.502	0.601	10.26	.356	0.623
	Female	28.88	.049		10.57	.084		10.12	.127	
	Generally	29.34	.492		10.71	.406		10.21	.291	
Right Bd	Male	21.04	.665	0.781	15.21	.530	0.446	8.39	.409	0.437
	Female	20.89	.176		14.87	.077		8.10	.332	
	Generally	20.99	.527		15.10	.447		8.30	.381	
Right GL	Male	126.33	.467	0.244	139.88	.827	0.982	129.79	.948	0.162
	Female	125.85	.042		139.90	.325		128.53	.445	
	Generally	126.17	.439		139.89	.657		129.37	.892	
Right SC	Male	10.01	.480	0.775	7.13	.493	0.874	5.13	.382	0.538
	Female	10.18	.954		7.19	.021		4.93	.148	
	Generally	10.07	.572		7.15	.383		5.06	.320	

GL: Length of bone; SC: The smallest corpus width of bone; Bp: Proximal width of bone; Bd: Distal width of bone. *p<0.05: Significance levels according to Mann-Whitney U test.

Table 2: Statistical analysis of measurement parameters of humerus, ulna and radius bones in terms of direction (right/left).

Gender	Direction	Humerus Mean value	Humerus Standard deviation	Humerus p-value	Ulna Mean value	Ulna Standard deviation	Ulna p-value	Radius Mean value	Radius Standard deviation	Radius p-value
Male	Left/Bp	28.61	.220	0.003*	10.25	.419	0.085	10.14	.196	0.293
	Right/Bp	29.57			10.78			10.26		
	Left/Bd	21.70	.428	0.055	15.75	.218	0.016*	9.05	.149	0.003*
	Right/Bd	21.04			15.21			8.39		
	Left/GL	125.15	.258	0.003*	140.24	.346	0.127	128.44	.605	0.021*
	Right/GL	126.33			139.88			129.79		
	Left/SC	9.73	.244	0.106	8.04	.069	0.001*	5.14	.177	0.876
	Right/SC	10.01			7.13			5.13		
Female	Left/Bp	28.29	.551	0.372	10.20	.148	0,178	10.10	.325	0.945
	Right/Bp	28.88			10.57			10.12		
	Left/Bd	21.43	.346	0.273	15.48	.374	0.263	8.99	.494	0.239
	Right/Bd	20.89			14.87			8.10		
	Left/GL	125.03	.820	0.392	139.55	.296	0.344	128.74	.480	0.648
	Right/GL	125.85			139.90			128.53		
	Left/SC	10.02	.742	0.806	8.28	.042	0.018*	5.09	.106	0.287
	Right/SC	10.18			7.19			4.93		

GL: Length of bone; SC: The smallest corpus width of bone; Bp: Proximal width of bone; Bd: Distal width of bone. *p<0.05: Significance levels according to Wilcoxon test.

DISCUSSION AND CONCLUSION

The existence of many birds of prey, especially red hawks, is necessary for the protection and continuity of natural balance. However, the numbers of birds of prey are decreasing due to the destruction of natural life, various accidents and hunting (injuring with firearms) (Coles 1985; Umar 1999). In many countries, including Turkey, legal regulations have been made regarding the hunting of birds of prey (Bostan 2000). Considering the conditions stated within the scope of the study, the materials used in the research were obtained from dead animals in order to prevent livestock losses and injuries.

In addition, it is thought that a total of six tissue samples belonging to males and females in the study are sufficient to explain the anatomy of the humerus and antebrachium in the endangered Red hawk species.

Most of the injuries that occur in wild animals due to various reasons are traumatic (Punch 2001; Deem et al. 2002; Buttle 2004). For this reason, radiological imaging methods are the most useful methods that veterinary clinicians can use in the diagnosis and treatment of injured or traumatized animals in the wild (Valente 2007; Borges et al. 2017). In addition, biochemical parameters cannot be used much during the diagnosis of injured wild animals. However, techniques such as radiography, computed tomography and magnetic resonance contribute significantly to the evaluation of biological data in endangered species and wildlife because they provide the best view of anatomical structures and organs, are non-invasive, and allow sensitive diagnoses (İşler 2018).

In accordance with general principles, the winged skeleton is very similar to the skeletal system of mammals. However, due to some ecological and biological factors, it can be said that avian and mammalian skeletal systems have many morphological features that differ from each other (Gültekin 1974).

In a study conducted on chickens, domestic ducks, pigeons and quails, the humerus was examined morphologically. In this context, it was reported that there was a caput humeri at the proximal end, a tuberculum laterale at the dorsolateral of the caput, and a crista tuberculi laterale extending outwards and downwards from here (Yıldız et al. 1998). It has also been stated that there is a tuberculum mediale in the dorsomedial part of the caput and a foramen pneumaticum, a large air hole, in the medial and distal parts of this medial tuber (Yıldız et al. 1998). It has been mentioned that there is a condylus ulnaris and a smaller condylus radialis at the distal end (Yıldız et al. 1998). Similarly, the morphology of the antebrachium bones (ulna and radius) has also been revealed (Yıldız et al. 1998).

When the humerus, ulna and radius in red hawks were examined morphologically, they showed complete agreement with the study in question. Studies have shown that the average length of the humerus has been reported; 72.5 mm in chickens, 46.1 mm in pigeons and 87.4 mm in domestic ducks (Yıldız et al. 1998), 67.77±0.55 mm in pheasants and 51.80±0.49 mm in partridges (Lök and Yalçın 2007), 172.5 mm in goose (Allison et al. 2006). In addition, the average length of the humerus has been reported 191.28±1.44 mm in male Kars goose, 175.02 mm, in female Kars goose (Dursun 2008), 12.20 cm in Pariah kite (Tiwari et al. 2011), 36.13±1.32 mm in Japanese quail (Demiraslan et al. 2014), 106 mm in male ducks, 95.84±1.63 mm in female ducks (Çevik Demirkan 2002), 62.3±4.11 mm in Commercial chickens and 58.0±1.41 mm in Desi chicken (Vistro et al. 2015).

According to the results of our study, the average humeral length in Red hawks was determined to be 125.11 mm in the left extremity and 126.17 mm in the right extremity, regardless of gender. In this context, it has been observed that Red hawks have the longest humerus among domestic and wild birds, other than geese species.

Humerus width is stated; 12.50±0.27 mm in male Kars goose, 11.84±0.35 in female Kars goose (Doğan and Takçı 2021), 2.30 cm in Pariah kite (Tiwari et al. 2011), 0.75±0.08 mm in Japanese quail (Demiraslan et al. 2014), 7.9±1.66 mm in Commercial broilers and 6.1±0.74 mm in Desi chicken (Vistro et al. 2015). In line with the results of our study, it was determined that the average humeral width in Red hawks, regardless of gender, was 9.83 mm in the left extremity and 10.07 mm in the right extremity. In this context, it has been observed that red hawks have the widest humerus among domestic and wild birds other than the geese species. It has been stated that the average ulna length in male domestic ducks is 100.1±3.0 mm (Charuta et al. 2005).

In addition, the ulna length was reported as 61.53±0.50 mm in pheasants (Lök and Yalçın 2007), 29.4 mm in wild quails, 29.7 mm in domestic quails (Yaman 1997), 13.60 cm in Pariah kite (Tiwari et al. 2011), 31.39±0.81 mm in Japanese quail (Demiraslan et al. 2014). The average width of the ulna has been reported 1.80 cm in the Pariah kite (Tiwari et al. 2011), 9.40-0.24 mm in the male Kars goose, and 8.72-0.32 mm in the female Kars goose (Doğan and Takçı 2021), and 0.69-0.12 mm in Japanese quails (Demiraslan et al. 2014).

The radius length was reported as 56.09±0.47 mm in pheasants (Lök and Yalçın 2007), 169.75±1.31 mm in male Kars goose, 154.20±1.63 mm in female Kars goose (Doğan and Takçı 2021), 91.0±13.59 mm in male Peking duck, 94.9±2.1 mm in female Peking duck (Charuta et al. 2005), 31.22±1.21 cm in Griffon vulture, 20.74±0.82 cm in flamingo (Frongia et al. 2021), 13.20 cm in Pariah kite (Tiwari et al. 2011) and 28.12±0.60 mm in Japanese quail (Demiraslan et al. 2014). The average width of the radius has been reported to be 1.10 cm in Pariah kite (Tiwari et al 2011), 6.28±0.28 mm in male Kars goose, 5.94±0.21 mm in female Kars goose (Doğan and Takçı 2021), and 0.35±0.05 mm in Japanese quail (Demiraslan et al. 2014).

According to the research results, the average Ulna length and width in the left extremity in Red hawks were determined as 140.01 mm and 8.12 mm, respectively, regardless of gender. The average length and width of the right extremity were determined as 139.89 mm and 7.15 mm, respectively. In addition, the average length and width of the left limb radius in Red hawks, regardless of gender, were 128.54 mm and 5.12 mm, respectively. Similarly, the average length of the right extremity radius was determined as 129.37 mm and its width was 5.06 mm.

When all studies are evaluated collectively, it is clearly seen that the ulna bone is thicker than the radius bone. Many studies include the average widths of the extremitas proximalis and extremitas distalis parts of the humerus, ulna and radius bones. Within the scope of the study, the average proximal and distal limb widths of Red hawks are similar to the results of the above-mentioned studies (Table 1 and 2).

In a study in which the front extremity bones of Red hawks were dissected and measured using calipers, the humerus It has been reported to be 10.5-11.7 cm in length, 0.75-0.90 cm in width. The ulna has been reported to be 11.4-13.2 cm in length, 0.56-0.78 cm in width and the radius has been reported to be 10.8-12.3 cm in length, 0.35-0.44 cm in width (Atalar et al. 2007). When the results of this study were compared with these results, it was seen that there was complete agreement. For this reason, it can be said that 3D images created by the computerized tomography method are an alternative method that can be used in live animals for morphological and morphometric measurements.

As a result, our study has shown that the anatomy of all wild animals, especially endangered birds of prey, can be examined with radiological imaging techniques such as computed tomography. We also believe that the results of this study will contribute greatly to the surgical treatment and care processes for humerus and antebrachium injuries in birds of prey.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.

AUTHOR CONTRIBUTIONS

Idea / Concept: VD, ZS, CG
Supervision / Consultancy: VD, ZS, CG
Data Collection and / or Processing: VD, CG, LA
Analysis and / or Interpretation: VD, ZS, CG, LA, GÇ
Writing the Article: VD, ZS
Critical Review: VD, ZS, CG, LA, GÇ

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