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Research Article

Morphometric Analysis of the Sternum in Avian Species

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Abstract: The anatomy of the sternum in avian species differs according to their movement and particularly flight capability, as well as species and habitat. Various studies aimed at the examination and measurement of the sternum in avian species have been carried out. However, to the authors' knowledge, no study on the correlation between sternal measurements and movement style has been published previously. In this study, the sternums of certain avian species including the red falcon (*Buteo rufinus*), rooster (*Gallus domesticus*), drake (*Anas platyrhynches*), bald ibis (*Geronticus eremita*), pigeon (*Columba livia*), white stork (*Ciconia ciconia*), eagle owl (*Bubo bubo*), goose (*Anser anser*) and turkey (*Meleagris gallopavo*) were investigated as 3 different habitant groups (I-flying, II- swimming and III- walking). Data analysis revealed a correlation between movement style and sternum measurements in avian species. In the swimming birds that were examined, the width (W) of the sternums was greater than the height (H), and W/H ranged between 1.56 and 1.95 mm. In contrast, the height of the sternum was greater than the width in walking birds and W/H was between 0.50 and 0.68 mm. In the flying birds the width and height of the sternum were approximately equal and W/H ranged between 0.96 and 1.35 mm.

Key Words: Birds, flight capability, osteology, sternum

Kanatlı Türlerinde Sternum'un Morfometrik Analizi

Özet: Kanatlı türlerinde sternum'un anatomisi, türlere ve yaşam şekillerine bağlı olduğu kadar hareket ve özellikle de uçma kabiliyetine göre farklılıklar göstermektedir. Geçmişte, kanatlı hayvanlarda sternum'un incelenmesini ve ölçüm yapılmasını amaçlamış farklı çalışmalar yapılmıştır. Fakat, sternum'un ölçüleri ile hareket tarzı arasındaki ilişki üzerine yayınlanmış bir araştırmaya rastlanılamamıştır. Bu çalışmada, yaşayan kanatlı türlerinden, kızıl şahin (*Buteo rufinus*), horoz (*Gallus domesticus*), ördek (*Anas platyrhynches*), kelaynak kuşu (*Geronticus eremita*), güvercin (*Columba livia*), beyaz leylek (Ciconio ciconio), puhu kuşu (*Bubo bubo*), kaz (*Anser anser*) ve hindi (*Meleagris gallopavo*) sternum'ları üç farklı yaşam grubuna ayrılarak (I-Uçan, II-Yüzen, III-Yürüyen) incelendi. Elde edilen verilerin analizi ile kanatlı türlerinde sternum ölçüleri ve hareket tarzı arasındaki bağıntı ortaya çıkarıldı. İncelenen kanatlı türlerinden yüzücü kuşlarda, sternum'un genişliğinin (W) yüksekliğinden (H) daha fazla olduğu ve W/H oranının 1,56-1,95 mm arasında değiştiği belirlendi. Bunun aksine, yürüyen kuşlarda sternum'un yüksekliğinin genişliğinden daha büyük olduğu ve W/H oranı 0,50 ile 0,68 mm arasında değiştiği tespit edildi. Uçan kuşlarda ise sternum'un genişliği ve yüksekliğinin yaklaşık olarak eşit ve W/H oranının 0,96 ile 1,35 mm arasında değişmekte olduğu belirlendi.

Anahtar Sözcükler: Kanatlı, uçuş kabiliyeti, osteoloji, sternum

Introduction

In carinate species the sternum is divided into 3 main parts: the corpus sterni, rostrum sterni, and carina sterni. There is a groove on the margo cranialis sterni, namely the sulcus articularis coracoideus, which serves for the articulation of the coracoid bone. There are 2 processes named the processus thoracicus cranialis and processus craniolateralis located on the craniolateral angle of the cranial border of the sternum (1-4). The rostrum (manubrium) sterni is a process for the attachment of the sternocoracoclavicular membrane. The sternal crest (carina or crista sterni) is located on the ventral surface

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of the sternal body, lying in a cranio-caudal direction. It is a feature to which the strong flight muscles (m. pectoralis, m. supracoracoideus) insert (5-7).

In general, the height of the sternal crest is related to flight capability. It is higher especially in strong flying birds (such as the pigeon). Hence, it is very low or even lacking in walking birds (1,4,8,9).

The anatomical features of the sternum vary in avian species, depending on their species, habitat, and mainly flight capability. Although many studies on the anatomical features of the sternum have been previously published (7,9-11), no correlation between sternal measurements and flying capability was described.

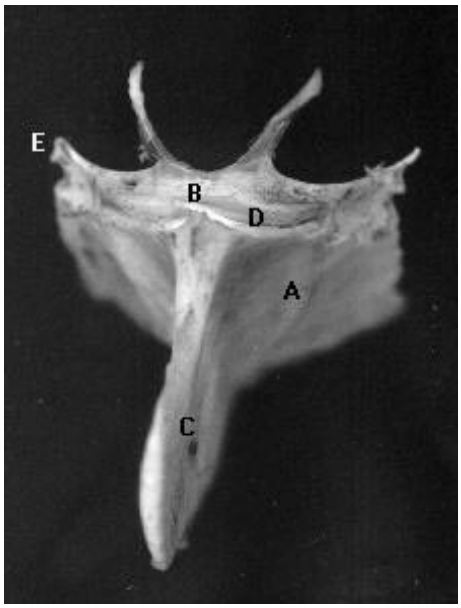
This study aimed to document the correlation between sternum measurements and flight capability in various avian species, classified as 3 different habitant groups (I-flying, II-swimming and III-walking). Calculation of a proportion by means of measurement of the durable parts of the sternum in existent avian species and correlation of the mentioned proportion with movement are foreseen to provide a basis for interpretation of the movement style of animals with reference to the carinate bird's sternum found in archaeological excavations.

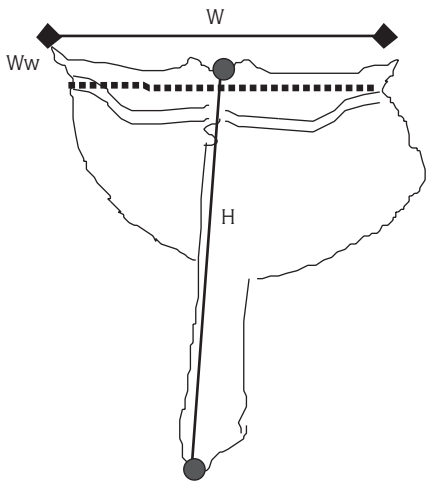
Materials and Methods

Thirty animals classified into 3 different habitant groups constituted the material of this study: 14 in the flying group, namely the red falcon, bald ibis, pigeon, white stork and eagle owl; 8 in the swimming group, namely the drake and goose; and 8 in the walking group, namely the rooster and turkey.

The sternums of all species were prepared for measuring as described by Taşbaş and Tecirlioğlu (12). The cadavers were boiled in water until the muscle tissue separated from the bones, and 10%-15% $NaHCO_3$ was added for whitening. Afterwards, they were left to dry. Osteometric measurements were performed using digital callipers (Tronic, 150 mm).

As indicated in Figure 1, the distance between the 2 craniolateral processes of the sternum (W), and that between the midpoint of the cranial border of the sternum and the highest point of the sternal crest (H) were measured. Thus, the distance (Ww) between the lateral ends of the 2 articular coracoid grooves was measured and analysed. Ww is an alternative measurement method of width, developed as a precaution against the possibility of damage of the craniolateral process of excavated sternums.





II- Measurement points of W, Ww and H on the sternum

Figure 1. I- The main anatomical parts and feature of the sternum (craniocaudal view).
A. Corpus sterni, B. Rostrum sterni, C. Carina sterni, D. Sulcus articularis coracoideus, E. Processus craniolateralis.

Nomina Anatomica Avium (5) was used as a reference for anatomical nomenclature.

Results

Sternums of the flying, swimming and walking birds possess anatomically different components. The width of the sternum (W) ranged between 24 and 65 mm in the flying group. The width (w) measurements of the sternums of the swimming and walking groups were 55-76 and 32-93 mm, respectively. The height (H) measurements of the sternums of the flying, swimming and walking groups were 23-63, 29-48 and 55-136 mm, respectively. The sternal crest, one of the main features of the sternum, was quite high in these 3 groups.

As seen in Figures 2a and 2b, values of W/H and Ww/H indicate that data pertaining to the sternum of the 3 different habitant groups greatly differ, and are set in 3 different scales. In addition, the Table summarises average values of W/H and Ww/H findings observed in all examined avian species.

Amongst the birds examined, the W/H value was 1.56-1.95 mm in the swimming group, 0.96-1.35 mm in the flying group, and 0.50-0.68 mm in the walking group. Likewise, the Ww/H value was 1.21-1.43 mm in the swimming group, 0.63-1.04 mm in the flying group, and 0.41-0.50 mm in the walking group.

Table. Average W/H and Ww/H values (mm).

Avian species	W/H	Ww/H
drake	1.86	1.33
goose	1.61	1.23
red falcon	1.17	0.89
pigeon	1.18	0.83
bald ibis	0.97	0.63
eagle owl	1.04	0.84
white stork	1.04	0.65
turkey	0.65	0.47
rooster	0.58	0.44

The width of the sternum was greater than the height of the sternum in the swimming birds examined (Figure 3a). However, the opposite was the case for walking birds (Figure 3c). Finally, these values were approximately equal in flying birds (Figure 3b).

Discussion

The literature (1,4,7,9,11) has documented a positive correlation between flight capability and the height of the

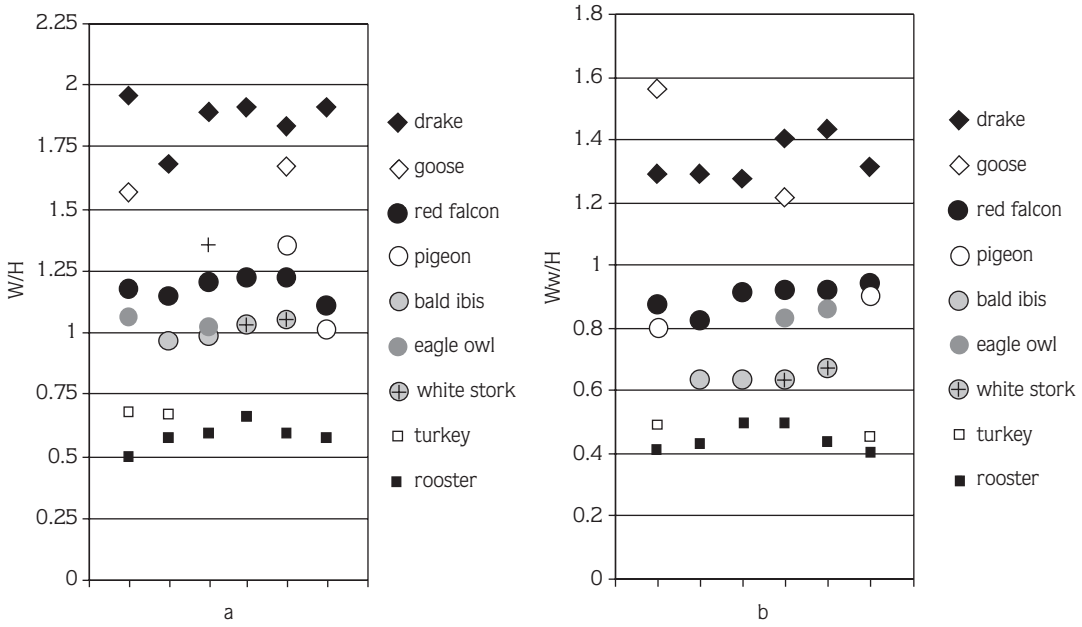


Figure 2. Two linear graphics pertaining to the values of W/H (a) and Ww/H (b) in all species investigated.

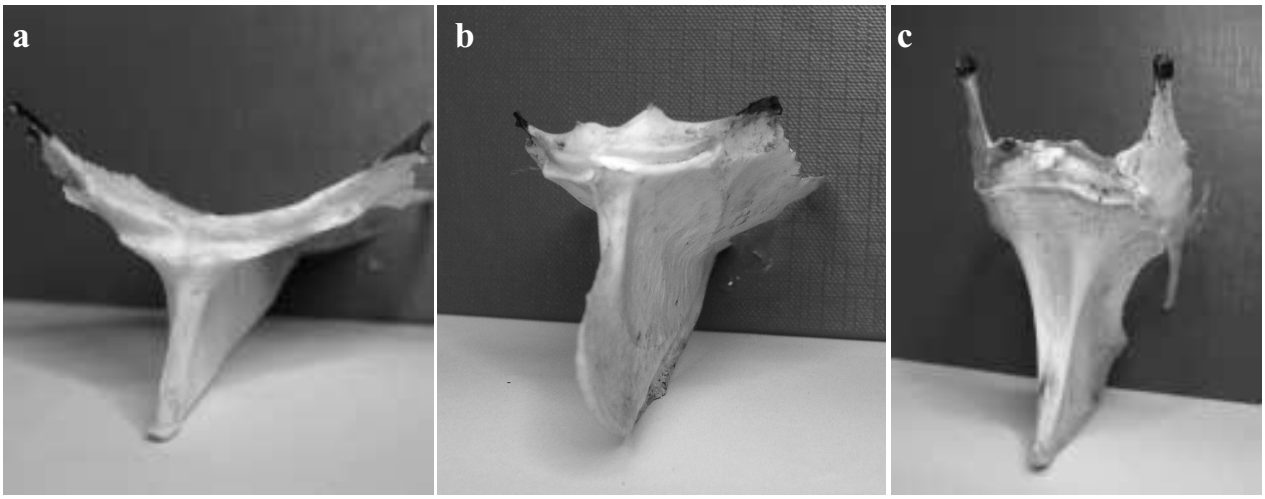


Figure 3. Sternums of 3 different habitant groups.
a. Swimming (drake), b. flying (bald ibis), c. running (turkey)

sternal crest to which flight muscles insert. This structure has been reported to be prominent and large in flying birds such as pigeons, and to be smaller or even to diminish in walking birds. The results of the present study, however, showed the sternal crest to be high in the 3 groups studied (flying, walking and swimming). For this reason, to conclude that birds with a higher sternal crest fly, while those possessing a lower sternal crest walk would not be correct. The carinata sternum of the pigeon, which flies, is not higher than that of the rooster, which cannot fly. If a conclusion on this matter is to be made, the results of this study suggest that the ratio of height and width of the sternum should be taken into consideration.

The above-mentioned results suggest a correlation between the W/H or Ww/H values of sternums and the capability of animals to fly, walk and swim. It is evident that the results of this study indicate a necessity to use the W/H or Ww/H ratio when estimating a correlation with flight capability.

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