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Morphometric Analysis of *Falco peregrinus peregrinus* Rescued in Pakistan

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RT planned and conducted experiments. KKY and JM funded the project and reviewed the manuscript. NS, JH, FA and NAR worte the manuscript and finalized it for publication.

Key words
Migratory birds, Indus flyway, Birds of prey, Avian diversity, Wingspan

ABSTRACT

Peregrine falcon *Falco peregrinus peregrinus* is recognized as the migratory species in the world. This falcon is one of the four subspecies of *Falco peregrinus.* These birds are poached in Pakistan during their migration. Fortunately, they were rescued by Pakistan Customs, Sindh Wildlife Department (SWD), and Raptor Center for Conservation and Rehabilitation, Pakistan (RCCRP) and were observed for this study. Several parameters were studied in the rescued birds for morphometric measurements including total length, wings pan, bill depth, bill width, bill length and tarsus in both male and female Peregrine falcon. Bill volume was also calculated with the given parameters which resulted in showing difference between the groups. Male and female individuals were also compared on the basis of body size and bill volume. The objective of this study was to determine the diversity among the individuals which will benefit while comparing adaptive radiations in avian fauna. This research can also be associated with diversification in birds for instance the structure of bill, wingspan, and total length which enables different functions in both sexes including feeding habits and flight patterns.

INTRODUCTION

Peregrine falcons (*Falco peregrinus peregrinus*) is widely distributed throughout the world except Antarctica. It is one of the fastest birds in the world. While diving to catch the prey, their speed can reach up to 150 km/hr (Ponitz *et al*., 2014). Like other falcons, they also have slender bodies, a long narrow tail, and pointed wings. The upper parts are pale bluish. The under parts are flawlessly white, heavily marked with clean and tidy spots and bars. Due to variation in color and sizes, they are classified into 19 subspecies, out of which at least five are migratory (White *et al*., 2013). The study of these falcons required proper handling and favorable environment as suggested by Williams *et al*. (2020) that photography can be used as a tool for morphometric measurements which will further reduce the stress in birds.

Pakistan is a rich country in terms of avian biodiversity due to a variety of habitats from permanent snow zones to alluvial plains and sandy deserts, which extends to the seacoast in the south. Pakistan hosts four sub-species of Peregrine falcon; *F. p. peregrinus, F. p. babylonicus, F. p. calidus* and *F. p. peregrinator* (Dixon *et al*., 2017). *F. p. peregrinus* got our attention to study because it is a migratory and threatened species in Pakistan. During this study, uncontrolled illegal trade of falcons was observed (Ahmad and Khan, 2020). Peregrine falcons are mainly captured by a method called Khudhu, in local language of Pakistan. In this technique, live baits such as kestrils and laggar falcons. They are tied with the feathers of quail/ partridge and nylon mesh. As the migratory bird sees the opportunity to snatch the prey from laggar falcon (live bait), it entangles itself in nylon mesh (Ahmad and Khan, 2020; Shafiq and Idrees, 2006).

It is now accepted that the species evolution generally progress by a continuously transforming characters. These characters display noticeable hereditary variations along with the environmental factors (Falconer, 1996). Our study

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presents analysis of some morphometric measurements of wild Peregrine falcons (*Falco peregrinus peregrinus*) rescued by the Sindh Wildlife Department and the Pakistan Customs, which were captured illegally from Indus plains of Pakistan en route to their migration which include Hadero, Keenjhar, Haleji, and other Sindh lakes (Shafiq and Idrees, 2006; Ghalib *et al*., 2019; Khan *et al*., 2024). The birds were kept in a temporary rehabilitation center, provided by Raptor Center for Conservation and Rehabilitation, Pakistan during the span of this study.

Up till now, Peregrine falcons have not been the subject of morphometric study in Pakistan. This study projects on morphometric aspects related to the species ecology and biology (Debus and Rose, 2000) as the species can be used as a part of a broader scientific investigations for raptor communities (Aumann, 2001a, b, c; Falkenberg, 2011; Sutton, 2011).

MATERIALS AND METHODS

The specimen comprised of one subspecies of Peregrine falcon, *F. p. peregrinus,* (n=56; females= 27, males= 29). All the alive specimen was identified with the help of previously reported literature and indigenous knowledge, gathered from falconers (Grimmett *et al*., 2008). Measurements of total body length (from the highest point of skull, without bill, to the tip of the tail feathers), wingspan (from farthest primary feather (number 10) of one wing to another), bill length (from end of cere to the tip of bill), bill depth (from the highest point of maxilla to the shallowest part of mandible, without cere), bill width (highest and widest point, without cere) (Fig. 1) and tarsus length (tarsometatarsus) of each bird was measured by using Vernier caliper (for bill, minimum count 0.01mm), measuring tape (minimum count mm) and weighing balance (minimum count g). The bill volume (mm^3) was deter$\frac{Bill\ length\ (L)\ x\ Bill\ depth\ (D)\ x\ Bill\ width\ (W)}{3}$

We made sure that the specimen had no broken feathers and the mandibles, which were completely closed. An individual bird was not handled more than ten minutes to minimize the stress which is a key factor in accuracy of the results. Measurements, including weighing of birds, were taken at the time of dawn when the birds were more relaxed and their crops were empty (Winker, 1998; Baldwin *et al*., 1931).

We assumed rescued falcons to be a portion of a greater population since they are migratory species. Descriptive statistics were calculated using Minitab 19. *t*-Test was performed for the analysis of variance to observe the significant differences between the mean values of the morphometric characters in male and female individuals. The morphometric data analyzed in this research allowed us to determine the variations in overall size of birds, which significantly indicate the diversity.

RESULTS

Table I shows the morphometric data of *F. p. peregrinus*. Females of Peregrine falcons were significantly larger than males in total length, body weight, wingspan, bill volume, and tarsus length. The mean total length was 422.63 ± 9.47 mm in females (range: 410-450 mm) and 381.86 ± 7.85 mm in males (range: 370-390 mm).

Table I. Descriptive statistics of morphometric characters of *Falco peregrinus peregrinus* (p-value 95%).

Morpho-metric charac-ters	Sex	Tot-al[1]	Mean ± SD[2]	DF[3]	Dif-fer-ence	T[4]	P[5]
Total length (mm)	Female	27	422.63 ± 9.47 (410-450)	50	40.77	17.47	0
	Male	29	381.86 ± 7.85 (370-390)				
Weight (g)	Female	27	914.99 ± 45.08 (794.14-979.65)	42	290.4	15.65	0
	Male	29	624.6 ± 88.3 (513.6-956.7)				
Wing-span (mm)	Female	27	997.89 ± 9.8 (988-1013)	30	77.4	7.64	0
	Male	29	920.45 ± 53.62 (830-972)				
Bill depth (mm)	Female	27	18.173 ± 1.574 (15.02-20.54)	53	2.394	5.37	0
	Male	29	15.779 ± 1.764 (13.23-18.65)				
Bill width (mm)	Female	27	12.827 ± 3.034 (9.08-18.01)	52	0.095	0.13	0.898
	Male	29	12.732 ± 2.714 (9.21-16.58)				
Bill length (mm)	Female	27	24.76 ± 0.91 (23.02-26.02)	46	3.764	11.54	0
	Male	29	20.995 ± 1.483 (19.26-23.03)				
Bill volume (mm^3)	Female	27	1931.1 ± 510.3 (1296-2798.1)	45	525	4.58	0
	Male	29	1432.9 ± 345.7 (935.3-1931.3)				
Tarsus (mm)	Female	27	58.3 ± 5.45 (50-67)	51	3.09	2.28	0.027
	Male	29	55.207 ± 4.609 (50-66)				

[1]N= Total, [2]Standard deviation, [3]Degree of freedom, [4]Test statistics, [5]Probability value

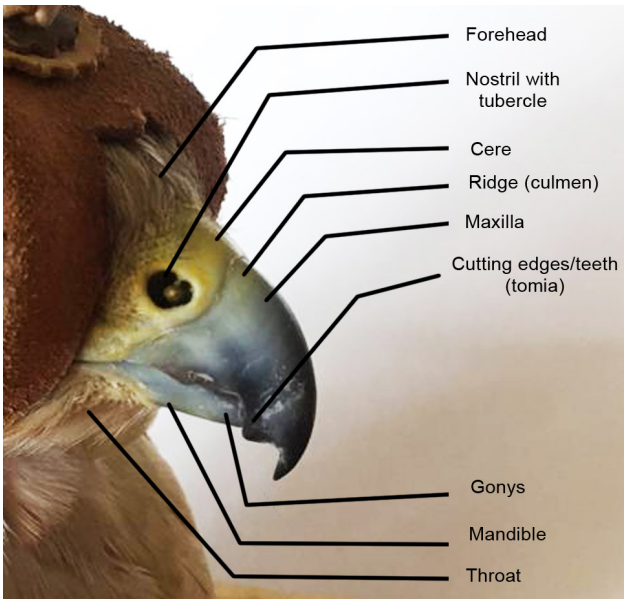

Fig. 1. Labelled mouth and bill parts of Peregrine falcon.

Similarly, wingspan ranged from 988 mm to 1013 mm in females and 830 mm to 972 mm in males, while tarsus length measured 58.3 ± 5.45 mm and 55.207 ± 4.60 mm in females and males, respectively. These differences confirm sexual dimorphism typical of birds of prey, where females tend to be larger. Although expected, quantifying such differences is important for ecological and taxonomic studies, aiding in accurate sex identification, understanding adaptive strategies, and monitoring population variation across regions or subspecies (Table II).

Table II. Allometry between different morphometric characters in different sexes of *F. p. peregrinus.*

Morphometric characters	Sex	N	y	r^2
Total length vs. Weight	Female	27	$29.123x^{0.57}$	0.0624
	Male	29	$23.262x^{0.5521}$	0.0086
Total length vs. Wing-span	Female	27	$198.97x^{0.2667}$	0.3608
	Male	29	$0.003x^{2.1237}$	0.5444
Total length vs. Bill volume	Female	27	$3E\text{-}15x^{6.7804}$	0.3953
	Male	29	$2E\text{-}22x^{9.6492}$	0.6125
Total length vs. Bill length	Female	27	$0.3919x^{0.6856}$	0.1657
	Male	29	$474956x^{-1.687}$	0.2449
Total length vs. Tarsus	Female	27	$4E\text{-}05x^{2.3362}$	0.3027
	Male	29	$0.1459x^{0.9979}$	0.0618
Bill length vs. Bill volume	Female	27	$5E\text{-}05x^{5.4115}$	0.612
	Male	29	$5E+06x^{-2.658}$	0.5051

DISCUSSION

Table II shows allometric relationship between different morphometric characters in the two sexes of *F. p. peregrinus.* The present study suggests that bill volume is highly significant in both male and female Peregrine falcons with respect to bill width, length, and depth. *F. p. peregrinus* possessed visibly diverse bill volume and the structure of the bill represents their feeding habits. Johansson *et al*. (1998) compared the bill size and the bill structure of Peregrines from the two different habitats and the result suggested no significant relationship. Similar findings are stated by Bierregaard (1978), which showed the relationship between bill depth and width among several groups of raptors, including *Falco*, as well as between bill depth and habitat.

Our study presents observation on bill volume. Bill volume showed greater growth rate than the body as whole. It was observed in both sexes. Similarly, bill length showed the highest growth rate relationship in females and lower growth rate relationship in males. A these are the first data on bill volume on raptors from Pakistan which is quite similar to the results of Beintema and Visser (1989) who used the bill length as universal age estimator and observed that the growth rate of body weight and bill length was constant throughout the developmental stages of chicks of Lapwings subfamily Vanellinae and other birds from order charadriiformes but the growth rate slowed down after 25 days.

This study also suggests that body weight has lower growth rate in both male (n=29) and female (n=27). Similar observations are reported in different birds such as, Teather and Weatherhead (1989) observed the nestlings of Great-tailed grackle or Mexican grackle (*Quiscalus mexicanus*) and noted that the larger sex had higher growth rate than the smaller one, Richter (1983) is of the view that smaller sex grows more quickly than the larger relative to their size in altricial birds (herons family Ardeidae, hawks family Accipitridae, owls family Strigidae and family Tytonidae, etc.), Nee *et al*. (1991) showed positive relationship in the abundance and body weight of several British birds, and Teather and Weatherhead (1994) denied any relationship between competing individuals that affect different patterns of growth and development in males and females.

The parameters observed during our study were also presented by a number of authors including research on African raptors kept by falconers and zoos, indicating male males of *Falco biarmicus* (Lanner falcon) had higher loads than females (Mendelsohn *et al*., 1989). Our result is in accordance with the above findings. Another study on bearded vulture *Gypaetus barbatus* highlights long and

heavier wings in adults than in juveniles (Brown, 1988). We found that difference between adults and juveniles was non-significant.

In our study, wingspan of female Peregrine falcons were found to be significantly longer than males. This is due to "reversed sexual dimorphism or RSD" in raptors, where females are larger than males (Mueller and Meyer, 1985; Krüger, 2005; Sullivan *et al*., 2019). Furthermore, smaller raptors capture prey more frequently than larger ones, this favors the male raptors for immediate chances of courtship (Safina, 1984). We have observed sexual dimorphism with significant difference between males and females in accordance with the above findings.

CONCLUSION

This is the first study on morphometric analysis of *Falco peregrinus peregrinus* from Pakistan. The study was designed to observe sexual dimorphism and any significant relationship between length, wingspan, bill volume, body weight, and tarsus length.

Our country lacks facilities/rehabilitation centers for birds of prey to deal with injured and sick with the goal of releasing them back to their natural habitat. Hence, it is highly recommended that work on establishment of rehabilitation centers on a smaller scale by concerned departments would change the current status of migratory species. The present study will be beneficial for the researchers or rescuing teams working on raptors in providing preliminary data on diversity among the individuals of same population, sexual dimorphism criteria, and growth parameters.

DECLARATIONS

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Ethical statement

We carried out this study under proper environmental conditions favorable for bird handling to reduce the stress in order to obtain accurate results. It is recommended that the use of photography as a tool for morphometric measurements can further reduce the stress in birds.

Generative AI and AI-assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Statement of conflict of interest

The authors have declared no conflict of interest.

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