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Clustering the tumbler pigeons group on their morphological characteristics reveals a eumetrical and a hypermetrical clade

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Abstract

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The objective of the research was to investigate the relationship among traits in 21 tumbler pigeon breeds and Rock Pigeon (*Columba livia*) from different traits(body weight, wing length, height, beak base thickness, beak length, nape length, neck thickness, tail length, tarsus length and tarsus thickness traits). In the principal component analysis with var-covar matrix it was found that for all traits first principal component explained more than 99.2% of the total variation, being bodyweight the most discriminative trait. Clustering analysis was performed based and results showed 2 multi-breed clades according to body weight. So we can conclude the existence of two main tumblers clades according to their body weight: a eumetrical group (with a body weight below 300 g) and a hypermetrical group (with a body weight above 300 g) in tumblers group. This kind of analyses can define clades, estimate admixture dates, distinguish geographically diverse populations, and help in the future to determine the source of shared mutations among diverse pigeon tumbler breeds.

Keywords: analytical detection function; classification; cluster analysis; *Columba livia;* Rock pigeon

Introduction

Domestic pigeons were derived from Rock Pigeon (*Columba livia*) by artificial selection perhaps 5000 years BP (Sambraus, 1989) (Johnston, 1992). There are currently more than 300 recognized breeds (http://pigeon-kingdom.blogspot.com/p/list-of-pigeon-breeds_16.html), which were obtained through division and admixture, and most of them with unique histories and perhaps genuine profiles(Shapiro et al., 2013).Importation and establishment of new types have an evident measurable effect on body structure, although some common traits among breeds may have independent origins (Parés-Casanova, 2010).

It is human nature to attempt to classify the things around us into groups based on similarity, "trees „representing a comprehensible view of relationships. When researchers want to categorize breeds, in order to figure out the morphological distance and their diversity, they use cluster analysis methods via mathematical formulas. Knowledge in pigeon phylogenetics is very scarce with very low amount of research in the breed-level taxonomy of these organisms (Shapiro & Domyan, 2013). This is unfortunate because for the hyperdiverse pigeon group there is a great deal of classification work (Parés-Casanova, 2010) (Domyan & Shapiro, 2017). Second, because much of the diversity that is being lost is unknown, including large numbers of pigeon breeds, and thirdly, diversity that is undocumented at present (for example, that which can be found in local populations) might contain genetic, but also cultural, material of value. Moreover, in general, as there is a loss of domestic animal diversity in the face of increasing pressures from modern farming, the study of pigeons have to be a cause for a concern, as is for other domestic species. So, our data potentially will have a general importance for the management and conservation of current pigeon genetic resources.

The main specific objective of this study was to conduct a phenotypic analysis exploring relationships and dependencies among a group of morphological traits for some tumblers breeds. The breeds are named so because of their ability to tumble backwards in flight. This ability has been known in domesticated pigeon breeds for centuries and it is believed to be a survival skill that these birds developed to evade aerial attacks by birds of prey. Tumbler pigeons group is more variable morphologically than others (Johnston, 1992). Pigeons from this group have been selected for their ability for tumbling or rolling behaviour in flight, to the extent that can no longer fly but, instead, tumble as soon as they intend to take wing (Sambraus, 1989). Wendell M. Levi, in his book *The Pigeon* (Levy, 1981), quotes that pigeons with a tumbling ability existed in India before the year 1590. And in Darwin's book *The Origin of Species* (Darwin, 1859), there is a reference to the Short Faced Tumbler(Levy, 1981), which was a popular breed during his lifetime, and still can be found exhibited at pigeon shows today. There exist many different tumbler breeds, which occur in a wide variety of size, plumage colours, body types and feather configurations (Sambraus, 1989) (Schille, 2005), and currently there are listed about 80 different tumbler breeds in the world (http://www.npausa.com/breeds/breeds_groups.html).

Research on pigeon breeds is interesting as it tells us a great deal about *Columba livia* domestication process, especially the way in which humans have shaped such extraordinary biological diversity in a relatively short period of time. Furthermore, it can give us a unique perspective on human cultures throughout the world.

Materials and Methods

We considered morphological traits belonging to 21 tumblers breeds and wild Rock Pigeon (*Columba livia*): Vienna Short-faced VIE, Komorner KOM, Show Tippler SHO, Iranian Highflyer IRA, Indigenous Lotan LOT, Par-

Table 1. Morphological data considered for the comparative study of 21 tumblers breeds and Rock Pigeon (*Columba livia*). See text for acronyms. Body weight appears in bold

	Weight (g)	Wing length (cm)	Height (cm)	Beak base thickness (cm)	Beak length (cm)	Nape length (cm)	Neck thickness (cm)	Tail length (cm)	Tarsus length (cm)	Tarsus thickness (cm)
VIE	230	19.0	18.5	1.1	1.2	4.1	4.3	8.8	2.3	0.6
KOM	250	18.0	21.0	1.0	1.4	2.9	5.8	10.0	2.3	0.6
ROC	278	22.2	19.0	1.2	2.3	4.1	4.3	11.0	3.0	0.6
SHO	280	22.8	19.0	1.0	1.6	3.2	5.2	12.0	2.5	0.6
IRA	290	24.5	18.9	1.1	1.8	4.8	5.9	12.0	2.4	0.6
LOT	290	22.0	17.7	0.9	1.8	4.9	4.4	11.0	2.8	0.7
PAR	290	22.3	15.0	0.9	1.4	3.7	4.8	12.0	2.1	0.4
MAG	300	22.5	18.0	1.2	2.2	5.2	4.0	10.4	3.3	0.6
IND	300	23.3	20.4	1.1	2.0	5.0	3.3	10.2	2.4	0.5
ERL	300	22.0	20.3	1.0	1.4	3.6	4.7	11.2	2.7	0.6
STA	300	22.5	28.0	0.9	2.0	6.8	4.8	11.0	2.7	0.6
TUR	310	22.0	15.5	0.5	2.0	4.2	5.3	10.0	2.1	0.5
HAM	320	22.0	22.0	1.0	1.5	4.5	5.4	11.0	2.7	0.6
SER	320	23.6	17.5	0.6	1.7	5.5	4.5	12.4	2.5	0.5
TIP	330	23.3	20.5	1.0	1.6	4.5	4.1	10.5	2.7	0.6
UZB	330	23.0	19.0	1.1	1.3	4.6	5.2	12.5	2.5	0.7
PAK	330	23.0	21.0	1.1	1.7	5.2	5.4	12.5	3.0	0.7
MOO	340	22.6	19.2	1.0	1.8	4.7	7.0	11.6	2.4	0.6
GER	340	22.7	22.7	1.0	1.5	3.8	6.0	11.5	2.5	0.7
NUN	360	21.7	22.8	1.2	1.6	4.0	5.5	10.5	2.3	0.6
BAL	360	23.0	20.4	1.1	2.0	4.7	5.0	11.0	2.6	0.7
PAT	400	24.0	22.0	1.1	2.0	5.5	4.9	12.4	2.4	0.5

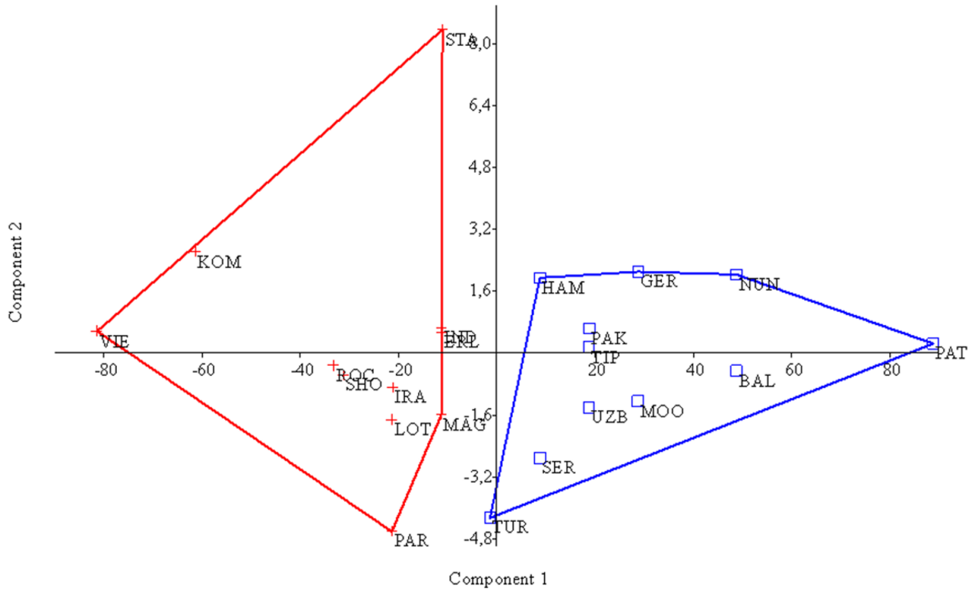

Fig. 1. Principal Component Analysis based on characters of 21 tumbler pigeon breeds and Rock Pigeon (*Columba livia*), for body weight, wing length, height, beak base thickness, beak length, nape length, neck thickness, tail length, tarsus length and tarsus thickness. See text for acronyms. A 99.2 % of the variation was explained by the first axe of the PCA plot which was defined mainly by the body weight (which a loading value of 0.999), with the rest of trait with loading values < 0.03

lour Roller PAR, English Magpie MAG, Indian Lotan IND, Erlau Tumbler ERL, Stargard Shaker STA, Turkish Tumbler TUR, Hamburg Helmet HAM, Serbian Highflyer SER, Flying Tippler TIP, Uzbek Tumbler UZB, Pakistani Highflyer PAK, Mookee MOO, German Nun GER, English Nun NUN, Bald-headed Tumbler BAL, and Parlour Tumbler PAT. Morphological traits included: body weight (interpreted as "body mass"), wing length (interpreted as "size"), height, beak base thickness, beak length, nape length, neck thickness, tail length, tarsus length and tarsus thickness. Most of this data were taken from the literature, but some supplementary unpublished observations by authors were also used. Data for Rock Pigeon was obtained too from literature (Uribe et al., 1985). In Table 1 there appear data for all studied breeds.

Data based were placed into a character matrix and were analysed by multivariate analysis, Principal Component Analysis (PCA) and clustering and Multivariate ANalysis Of VAriance (MANOVA). PCA was performed from var-covar matrix to identify accession groups and to determine the axes and the characters significantly contributing to the variation. Hence using principal components instead of explanatory variables gained both reduction of the explanatory data set and broke the co linearity. Clustering analysis can be used to classify the variables based on different linkage methods when classes initially not known. Cluster analysis for grouping breeds was Ward's method using Euclidean distance. Distance among clusters defined with corresponding linkage methods by ward method, increases in sum of squares within clusters. A K-means clustering, a non-hierarchical clustering method was finally applied to study clustering according to only a trait. All analysis were performed with PAST software (Hammer et al., 2001) with a significance level of 95%.

Results

Ten descriptors were used for the characterization of the breeds. The discrimination within the breeds under investigation revealed that 99.2% of the variation was explained by the first axe of the PCA plot which was defined mainly by the body weight (which a loading value of 0.999), with the rest of trait with loading values < 0.03. Two groups are clearly differentiated (Figure 1). Body weight and wing length were not correlated ($r = 0.403$, $p = 0.062$), indicating that as the weight increases or decreases it is not going to do the same with the wing length (remember that we interpret body weight as "body mass" and, wing length as "size").

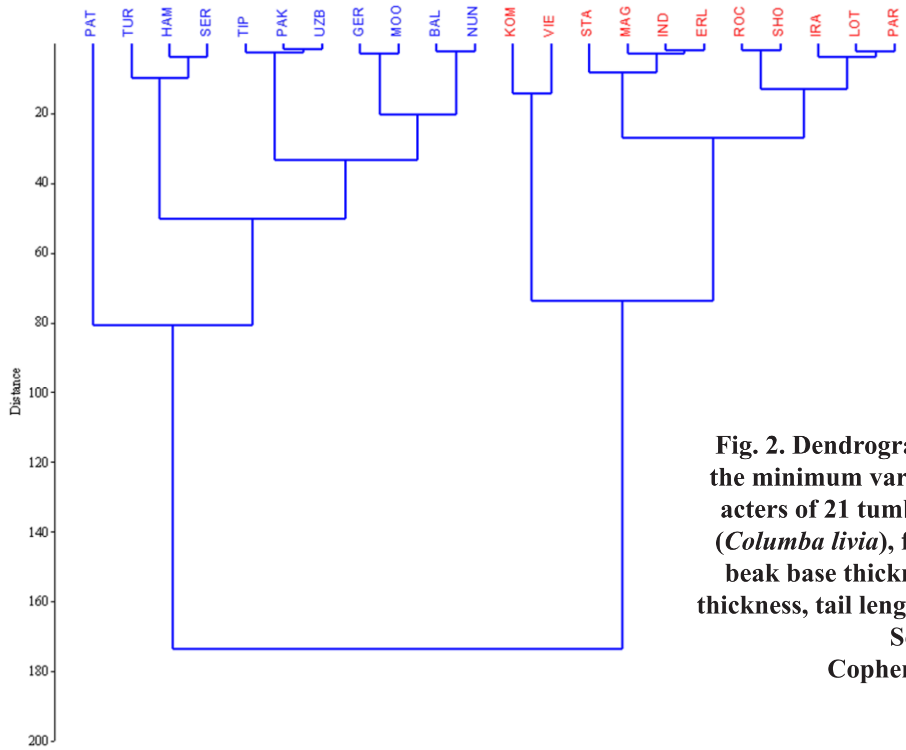

Fig. 2. Dendrogram resulting from cluster analysis of the minimum variance method (Ward) based on characters of 21 tumbler pigeon breeds and Rock Pigeon (*Columba livia*), for body weight, wing length, height, beak base thickness, beak length, nape length, neck thickness, tail length, tarsus length and tarsus thickness. See text for acronyms. Cophenetic correlation was 0.572

Based on morphological descriptors, the breeds clustered into two main groups (multi-breed clades) as revealed in the dendrogram (Figure 2), with a cophenetic correlation of 0.572. Analysis of variance confirmed this grouping ($F_{10,11}$ = 5.058, Wilk's λ = 0.178, p = 0.0065). Both clades could be differentiated by body weight(Parés-Casanova, 2013): group 1 (Vienna Short-faced, Komorner, Show Tippler, Iranian Highflyer, Indigenous Lotan, Parlour Roller, English Magpie, Indian Lotan, Erlau Tumbler and Stargard Shaker, and Rock Pigeon *Columba livia*) showing a body weight <= 300 g (range: 230–300 g), while group 2 (Turkish Tumbler, Hamburg Helmet, Serbian Highflyer, Flying Tippler, Uzbek Tumbler, Pakistani Highflyer, Mookee, German Nun, English Nun, Bald-headed Tumbler and Parlour Tumbler) having a body weight > 300 g (range: 310–400 g). The K-means clustering revealed that except Turkish Tumbler, with a body weight of 310 g, all tumblers are correctly assigned to the correct eumetrical (<= 300 g)or hypermetrical group (> 300 g). No elipometrical breed (< 200 g) can be considered, although there are some pigeon breeds below this body weight (one of the most extreme being the Catalan breed "Valencian Figureta", 150–170 g) (https://www.fesacocur.es/razas-espanolas/razas-de-palomas/palomas/figurita/).

Discussion

The present study revealed the morphological (not phylogenetical) relationships of some tumblers breeds from very different geographical regions using 10 morphological descriptors. These descriptors were used to estimate the phenotypic heterogeneity among those breeds and to identify the traits contributing to their diversity. Two multi-breed clades permitted a clear discrimination of breeds according to their body weight, so rendering a eumetrical group (with a body weight below 300 g) and ahypermetrical group (with a body weight above 300 g). Perhaps the inexistence of elipometrical tumblers can be explained by a mere biomechanical cause, as we have found no relationship between size and body mass and so very small pigeons would not necessarily present small sizes, so rendering a lack of flight efficiency. Moreover, the use of molecular genetics will allow a better understanding of how the events of breed formation and their relationships took place.

Conclusion

According to our results, based on morphological traits, there are two main tumblers clades according to their body weight: a eumetrical group (with a body weight below 300 g) and a hypermetrical group (with a body weight above 300 g) in tumblers group.

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Conflicts of interest

The authors are not conversant of any memberships, financial holdings or affiliations that could raise a conflict of interest.

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