Determining the Relation Between Brain and Body Mass Across Species of Birds

Evolution BIO461

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**Abstract**

The purpose of this study is to determine if there is a correlation between brain size and body size in birds. Larger body size in birds is unfavorable as it can reduce their flight abilities and carries large metabolic costs (Sukhum et al. 2016). It is possible there is a linkage between the genes for brain and body mass, such as when brain size increases, so will body size. Using a log-log regression analysis and Pearson’s correlation test, it was determined there was a positive correlation between these two variables across 620 species of birds. Further research is needed to determine if this correlation is due to a genetic linkage, or by other evolutionary processes.

**Introduction**

Despite the metabolic costs that large brains carry, researchers have continuously debated if brain size is an indicator of cognitive ability (West 2014, Sukhum et al. 2016). Brain size and body size have an allometric relationship across species, allowing researchers to predict that brain size has some correlation to body size (West 2014, University et al. 2014). It has not yet been determined whether this correlation is due to selection, genetic linkage, or other evolutionary processes in Aves. In humans, it has been determined that a strong selection to increase brain size has also resulted in an increase in body size (Grabowski 2016).

Aves are especially interesting as their body mass could affect their flight abilities by shortening the duration that they can fly, or thwart their ability to fly at all, disturbing their normal migratory patterns. Flightless birds could also be affected, as body size could affect their ability to walk, forage, or reproduce (Jordan 1995). Studying the correlation of brain and body size in non-avian reptiles, humans, and other mammals has allowed researchers determine the possible selective pressures on our ancestors (Grabowski 2016). It is possible that there is a genetic linkage between brain size and body size and birds, such as if selection is acting to increase brain size, body mass will also increase.

The correlation of brain to body size has been studied previously using log-log plots, allowing researchers to determine power relationships (Font et al. 2019). Phylogenetic generalized least square (PGLS) regressions are also used to study these correlations within species as they account for co-variance between samples. It is important to account of non-independence of data as individuals from the same taxa will likely closely resemble one another (Mundry 2014).

The purpose of this study is to determine the correlation between brain and body mass across 620 species of Aves. The class Aves is often used for research purposes due to their resemblance in behavior to mammals and wide distribution (Konishi et al. 1989). A log-log regression analysis will be used to identify the relationship between the two variables and Pearson’s correlation test to determine the strength of this correlation.

**Methods**

Data for brain mass was collected from a paper that used whole brain mass (Jiménez-Ortega et al. 2020). Measurements for brain mass came from weighing the mass of the brain (g) or by filling the skull of birds with lead shot. For the lead shot method, values were converted grams by multiplying the value by the density of fresh brain tissue (Jiménez-Ortega et al. 2020). Data for body mass comes from direct measures of body mass (g). Data collected came from species in captivity, species in the wild, and some unknown habitats. Brain mass and body mass were collected for 620 species of birds. Data was downloaded from Dryad and imported to R version 4.2.2 for data analysis.

Data analyses performed include a log-log regression and Pearson’s correlation test of 620 species of birds. The phytools package was used to perform all analyses. Conditions assumed for Pearson’s correlation include normal distribution, homoscedascity, linearity, continuous variables, paired observations, and no outliers.

**Results**

The log of each brain mass and body mass was used to generate a log-log regression scatterplot (Figure 1). The species with the greatest body mass and brain mass is *Aptenodytes forsteri* (Figure 1). The species with the lowest body mass and brain mass is *Archilochus colubris* (Figure 1).

**Chart, scatter chart

Description automatically generated**

Figure 1: Log regression analysis displaying the allometric relationship between brain and body mass in 620 species of birds.

The Pearson’s correlation coefficient is 0.80 (Figure 2). The Pearson’s correlation coefficient was rounded to the nearest tenth (Figure 2). A Pearson’s correlation coefficient for species found in captivity is 0.83. The Pearson’s correlation coefficient for species found in the wild is 0.77.

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| --- | --- | --- | --- |
| **p-value** | **Degrees of Freedom** | **95% CI** | **Pearson’s Correlation Coefficient** |
| 2.2x10-16 | 618 | 0.77-0.83 | 0.80 |

Figure 2: Pearson’s Correlation Coefficient between brain and body mass across 620 species of birds.

**Discussion**

The data used for this analysis was collected from birds occupying different habitats; birds were either found in the wild, in captivity, or had an unknown habitat. Three-hundred and forty-five species of birds were found in the wild, 134 species in captivity, and the remaining 141 were from an unknown habitat. It is possible that birds found in the wild were malnourished when compared to those in captivity, leading to inconsistent results. Correlation tests were performed for birds in captivity and those in the wild and both were consistent with the Pearson’s correlation test for all data and yielded a positive correlation.

The analysis performed in this study did not account for the phylogenetic relationships between data. It can be assumed that disparities in results are not due to non-independence of data because of previous studies performed, including the one performed by Font et al. A phylogenetically corrected regression was performed by Font et al. which also found a positive correlation between brain and body mass across 934 species of birds.

The Pearson’s correlation coefficient is 0.80 (rounded to the nearest tenth) between brain and body mass across 620 species of birds (Figure 2). There is a positive correlation between brain and body mass in the species examined in this study. As there is a strong directional selection towards reduced body mass in birds, the results obtained from this study could be hypothesized to be due to an even stronger selection towards increased brain mass in birds (Font et al. 2019). Increased brain mass is favorable as larger brains can be correlated to increased cognitive abilities in humans, though further research is needed to determine if this is consistent in birds (Lee et al. 2019).

Larger brains in birds are correlated with reduced death rates due to the increased ability to forage and escape predation (Cromie 2007). This in turn increases reproductive success, allowing species of birds with larger brains to generate more offspring as they are likely to have longer life-spans (Cromie 2007). The parameters of this study cannot determine why there is a linear relationship between brain and body mass across species of birds. It can be hypothesized that there is a possible genetic linkage between brain and body mass. In obese humans a genetic linkage has been found between body mass index and multiple genes expressed in the brain (Speakman 2013). No research could be found for the exact genes or linkage between brain and body mass across species of birds. Further research is needed to determine the presence of genetic linkage between these traits, or if there are other evolutionary processes determining this correlation.

**Data Availability**

All data and R studio code for analysis can be accessed through GitHub (<https://github.com/avereetorres/tasks/tree/main/Project>).

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