Run Faster, Jump Higher:

The influence of limb symmetry on anole locomotion

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Introduction

Fluctuating asymmetry describes nondirectional deviations between bilaterally symmetrical structures in an organism. Several studies, suggest these random occurrences result from environmental or genetic stressors (Vervust et al., 2008). As a fluctuating asymmetry of limbs could affect locomotor ability (Didde and Rivera, 2019). The relationship between limb asymmetry and locomotion is therefore important to evaluate so that we better understand how environmental and genetic stressors may be impacting an organism's ability to locomote through its environment. In this work, the magnitudes of asymmetry between the left and right femur of green anoles (*Anolis carolinensis*) were evaluated and compared with maximum sprint speed and jump power. These data were used to answer the question:

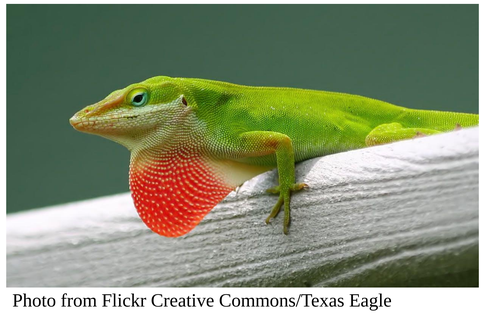
How does limb symmetry impact locomotor function?

Predictions:

(1) We predict that the shape of the left and right femora within a green anole individual are going to be more similar to one another than to the femora of other individuals

(2) We predict that fluctuating asymmetry in the anole's femora will be a significant component of shape variation

(3) We predict that the degree of femoral asymmetry in green anoles is correlated with locomotor variables (sprint speed, jump power) and that smaller magnitudes of asymmetry will be correlated with increased locomotor performance



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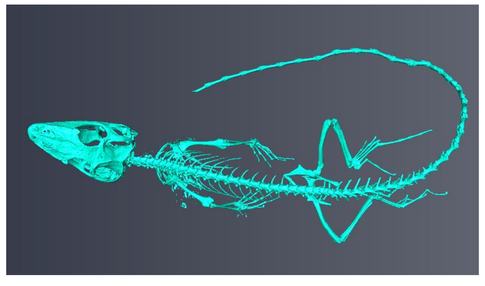


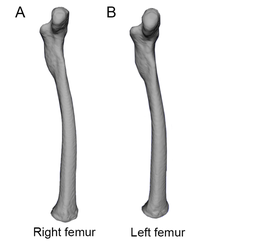
Figure 1: Green anoles (*Anolis carolinensis*) are common lizard species in the Southeastern United States and are found across New Orleans (top). These lizards were collected as part of a different project where their locomotor abilities were measured. Their bodies were CT scanned, then skeletally segmented to only show their bones. Their femora were then separated and used as the raw data in our analyses.

Methods

Examined individual asymmetry levels in green anoles (*Anolis carolinensis*) by segmenting the right and left femora into 3-D models from several micro-CT scans in the computer program Avizo

Digitally landmarked the 3-D models to establish the most accurate shape of each sample anole's left and right femora

Performed a Generalized Procrustes Analysis (GPA) in the coding program R. Asymmetry was calculated as the Procrustes distance between the right and left femur of an individual. ANOVAs were used to deter how levels of asymmetry correlate with the two locomotor measures (sprint speed and jump power)



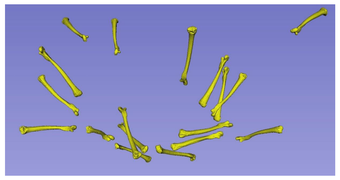


Figure 2: Top–Right and left femora (right reflected). Bottom–Femora used in the analysis prior to GPA

Results – Prediction 1

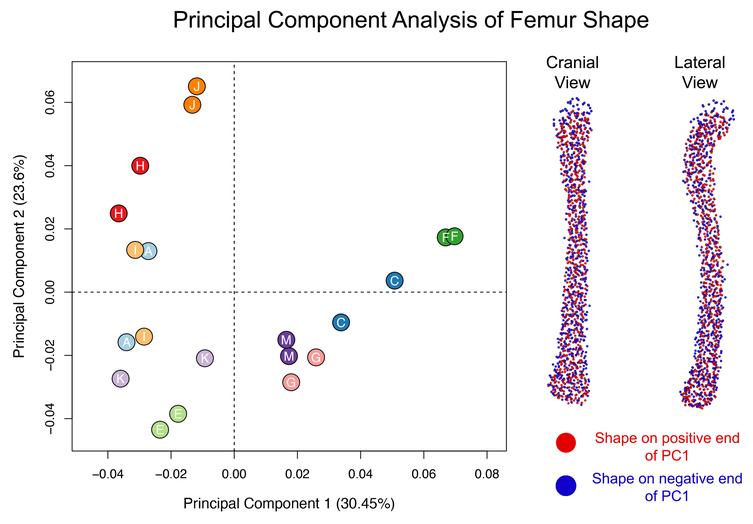


Figure 3: Principal Component Analysis of shape data. Rights and lefts are displayed as the same color with the same letter (e.g., Individual J is orange). Generally, femora from the same individual plot close to one another (with the exception of individuals A and I). This supported prediction 1. To the right of the PCA are the landmarks showing shape change along PC1. Red points are shapes on the positive end of PC1 while blue points are on the negative end of PC1. Femur is shown in two views.

Results – Prediction 2

	df	SS	MS	R2	F	p-value
Individual Variation	9	0.063	0.007	0.833	5.509	**0.001**
Directional Asymmetry	1	0.001	0.001	0.015	0.904	0.571
Fluctuating Asymmetry	9	0.011	0.001	0.151		
Total	19	0.076				

Table 1: Individual variation accounted for the majority of shape variation in the data (83.3% of total shape variation). However, fluctuating asymmetry accounted for 15.1% of total shape variation supporting our second prediction

Results – Prediction 3

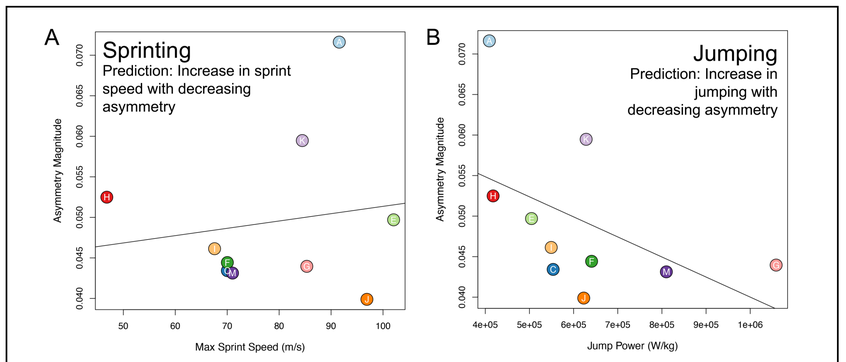


Figure 4: **(A)** Sprinting speed was not correlated with asymmetry and currently supports the trend opposite to our prediction (albeit not significantly). **(B)** Jump power was inversely correlated with magnitude of asymmetry supporting our prediction that as lizard femora become more asymmetric, their jump power decreases.

Conclusions and Future Directions

***Prediction 1*:** The data (Figure 1) supports our idea that the left and right femora of a single individual are more similar to one another than to femora of other individuals

***Prediction 2*:** The data (Table 1) supports the idea that fluctuating asymmetry is a significant component of the green anole's shape variation in femora

***Prediction 3*:** The data (Figure 4) does not support our idea that femoral asymmetry is correlated with sprint speed because the graph trend proved to be inconclusive, but the data does support our idea that femoral asymmetry is correlated with jump height because the small magnitudes of asymmetry related closely to performance.

In the future, we will gather a larger sample size of green anoles, acquire CT scans, and segment bones for statistical comparison. The next phase of this study will include more femora, humeri, and crania. Eventually, this work will help to understand how limb symmetry impacts locomotor function and fitness.

References:

-Didde, R. D., & Rivera, G. (2019). Patterns of fluctuating asymmetry in the limbs of anurans. *Journal of Morphology*, *280*(4), 587-592.

-Vervust, B., Lailvaux, S.P., Grbac, I. and Van Damme, R., 2008. Do morphological condition indices predict locomotor performance in the lizard *Podarcis sicula*? *Acta Oecologica*, *34*(2), pp.244-251.

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