A comparison of fluctuating asymmetry models in non-human primate crania

Ashly N. Romero and Claire E. Terhune

Department of Anthropology, University of Arkansas

Introduction

Fluctuating asymmetry (FA) is random deviation from bilateral symmetry in an organism or population, and FA is associated with stress experienced during growth and development[1-3]. How an organism responds to perturbations during ontogeny reflects its developmental stability and canalization[4,5]. Genetic stresses such as inbreeding and hybridization and environmental stresses like habitat loss, toxin exposure, and malnutrition disrupt development and decrease an organism's ability to follow a genotypic developmental trajectory (i.e., developmental stability) and produce a consistent population-wide adult phenotype (i.e., canalization). Fluctuating asymmetry may be influenced by growth rate; two models currently exist for FA in the adult form:

- FA accumulation: FA accumulates throughout ontogeny → slower growth = more FA[6]
- FA compensation: FA is compensated for throughout ontogeny → slower growth = less FA[7,8]

Gorilla growth constant = 0.39[9]

Pan growth constant = 0.28[9]

Research Question and Hypotheses

This study investigates how craniofacial FA varies with growth rate in *Gorilla gorilla gorilla* and *Pan troglodytes troglodytes*.

H_1: *Gorilla gorilla gorilla* will exhibit lower levels of FA than *Pan troglodytes troglodytes* due to their faster growth rates.

H_2: Males will exhibit lower levels of FA than females in both taxa due to their faster growth rates[10].

Materials and Methods

This study examined adult crania from the sympatric subspecies ***Gorilla gorilla gorilla*** and ***Pan troglodytes troglodytes*** (n=81). Landmarks were placed on 3D surface models collected from specimens at CMNH and USNM (Figure 1).

Genus	Female	Male	Total
Gorilla	22	22	44
Pan	17	20	37

74 3D landmarks:

- Base (2 midline; 6 bilateral)
- Face (5 midline; 19 bilateral)
- Vault (1 midline; 8 bilateral)

Statistical analyses:

- Procrustes ANOVA for FA detection
- *T*-tests using FA scores for testing differences between taxa and sexes within taxon
- ANOVA on FA scores for testing taxon*sex interaction
- Regression of FA scores on log(CS) to investigate relation to size
- Spearman rank correlation to determine correlation between FA and growth rate
- All analyses repeated by cranial region

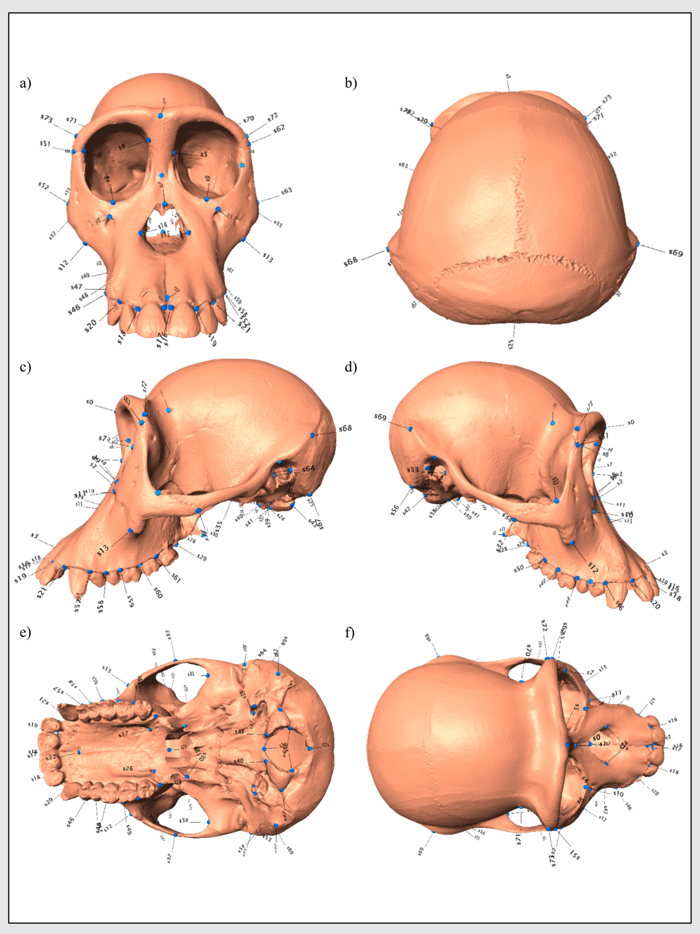


Figure 1: Landmarks

Results

FA was present in all groups and cranial regions ($p<0.0001$ for all). The regression of FA on size was significant but only explained 10% of the variation observed ($r^2=0.103$; $p<0.01$). No significant taxon*sex interaction was present in FA scores ($p=0.19$).

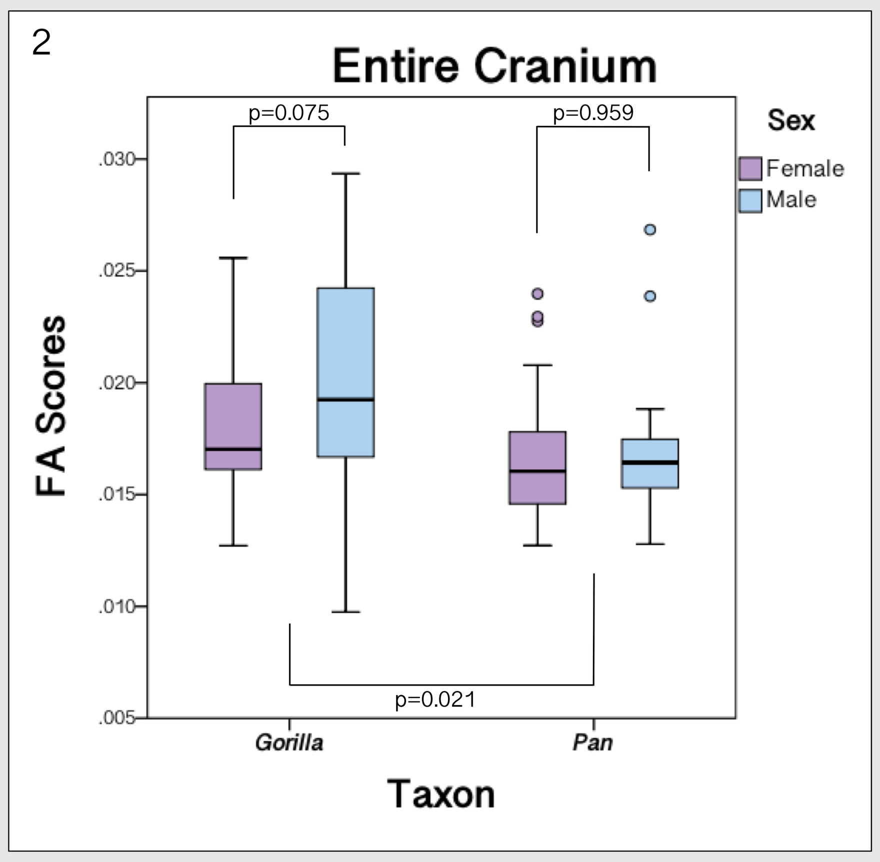


Figure 2: Boxplot of overall FA scores with *t*-test results between groups

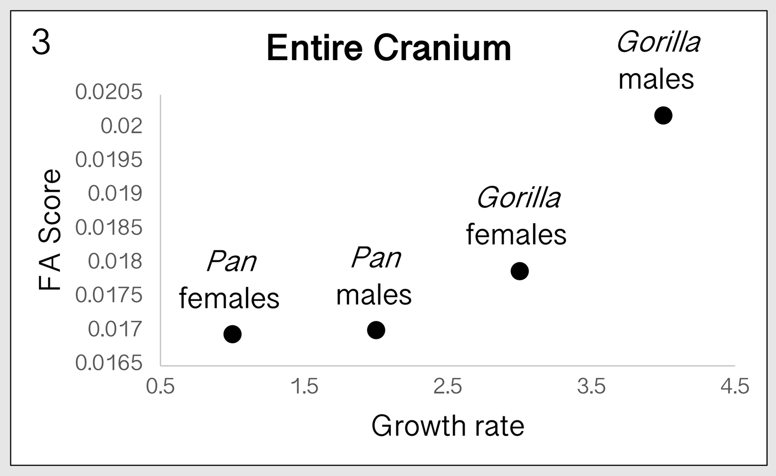
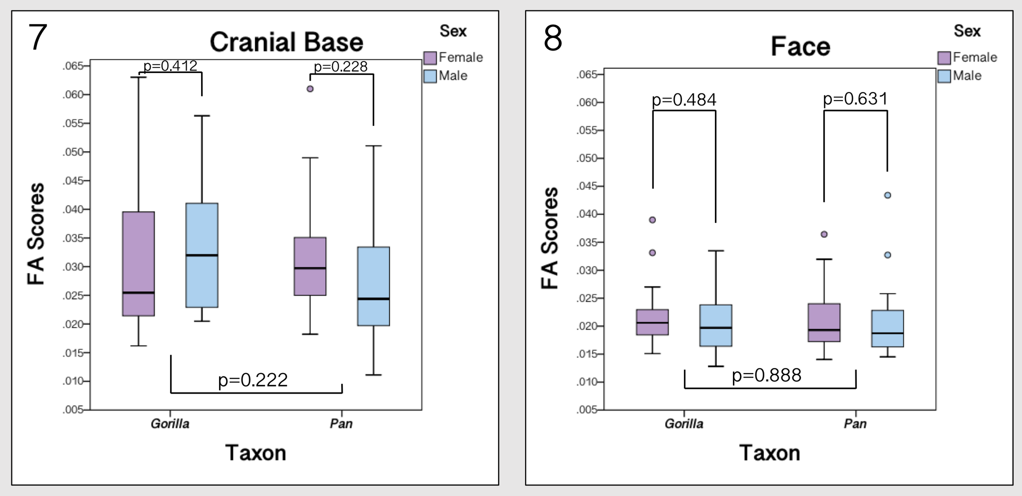
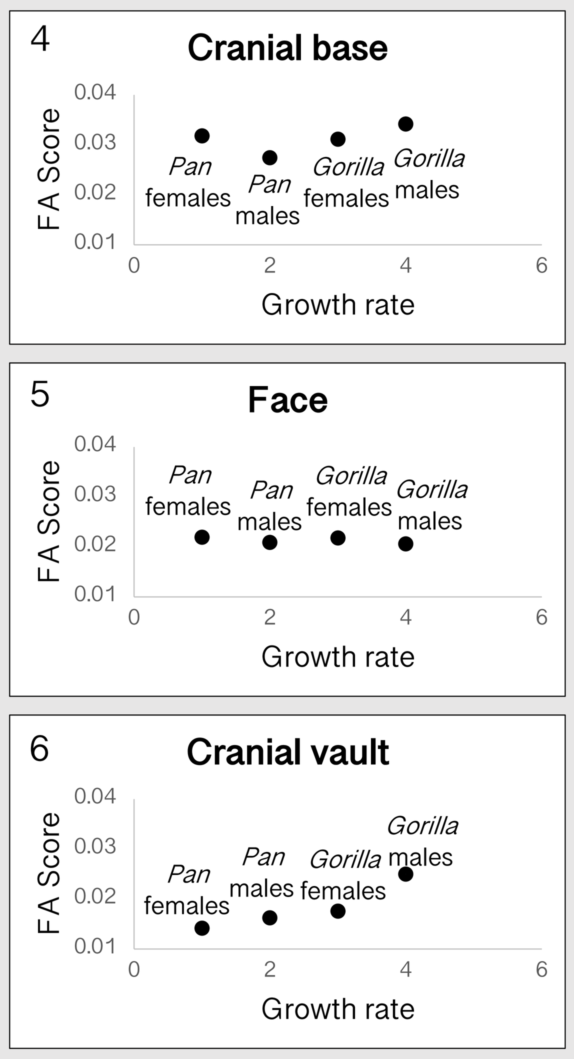


Figure 3: Spearman rank correlation between median FA scores and ranked growth rate

We observed a significant difference in FA between *Gorilla* and *Pan*, but no significant difference in FA between sexes in either taxon for FA calculated with all 74 landmarks (Figure 2). The Spearman rank correlation for FA and growth rate using all landmarks = 1 (Figure 3).



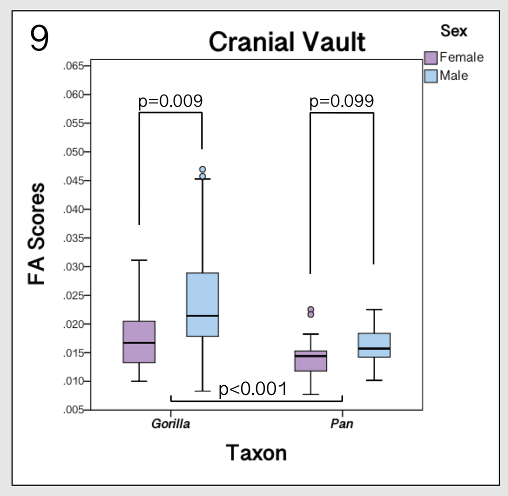


Figures 4, 5, and 6: Spearman rank correlations between FA scores and ranked growth rate by cranial region

The Spearman rank correlation for each cranial region was as follows:

→ Base = 0.4
→ Face = 0.6
→ Vault = 1

These correlations are graphically represented in Figures 4, 5, and 6.



Figures 7, 8, and 9: Boxplots of FA scores by cranial region

Significant differences in FA between taxa only exist in the cranial vault, and significant differences between sexes with a taxon only exist in the *Gorilla* cranial vault (Figure 9).

These data suggest that levels of FA are correlated with growth rate in the cranium, especially in the cranial vault. Note that individual FA scores cannot be directly compared between cranial regions because they were calculated in different morphospaces.

Discussion and Conclusion

These results indicate that groups with faster growth rates exhibit higher FA levels, suggesting H_1 can be rejected. H_2 cannot be either supported or rejected because the results regarding sex were inconclusive. Fluctuating asymmetry is a multifactorial and nonspecific indicator of stress, but growth rate is likely an important factor in FA development. Factors influencing FA in these specimens could be any of the following:

- Gorillas prioritizing faster growth rather than developmental stability,
- Chimps evolving greater developmental stability,
- Tougher and less nutritious gorilla diets incurring more muscle strain and malnutrition, or
- Different stress levels overall.

Furthermore, these results could support the FA compensation model rather than the FA accumulation model for these taxa because groups with faster growth rates might have less time to accrue FA.

Acknowledgements

We thank the Smithsonian Institution's Division of Mammals (Dr. Kristofer Helgen) and Human Origins Program (Dr. Matt Tocheri) for the scans of USNM specimens used in this research. These scans were acquired through the generous support of the Smithsonian 2.0 Fund and the Smithsonian's Collections Care and Preservation Fund. Additionally, we thank the Cleveland Museum of Natural History's Physical Anthropology Department (Dr. Yohannes Haile-Selassie; Lyman Jellema) for access to the non-human primate specimens from the Hamann-Todd collection used to create 3D surface models for this study.

References

1 Van Valen. 1962. Evolution 16(2):125-142. **2** Palmer and Strobeck. 1986. Annu Rev Ecol Syst 17:391-421. **3** Parsons. 1992. Heredity 68(4):361-364. **4** Waddington. 1942. Nature 150(3811):563-565. **5** Zakharov and Graham. 1992. Developmental stability in natural populations. **6** Hallgrímsson. 1999. Int J of Primatol 20(1):121-151. **7** Emlen, Freeman, and Graham. 1993. Genetica 89(1-3):77-96. **8** Kellner and Alford. 2003. Am Nat. 161(6):931-947. **9** Mumby and Vinicius. 2008. Evol Bio 35(4):287-295. **10** Leigh and Shea. 1996. Am J Phys Anth 99(1):43-65.

Contact

Ashly Romero
anromero@uark.edu
terhunelab.uark.edu