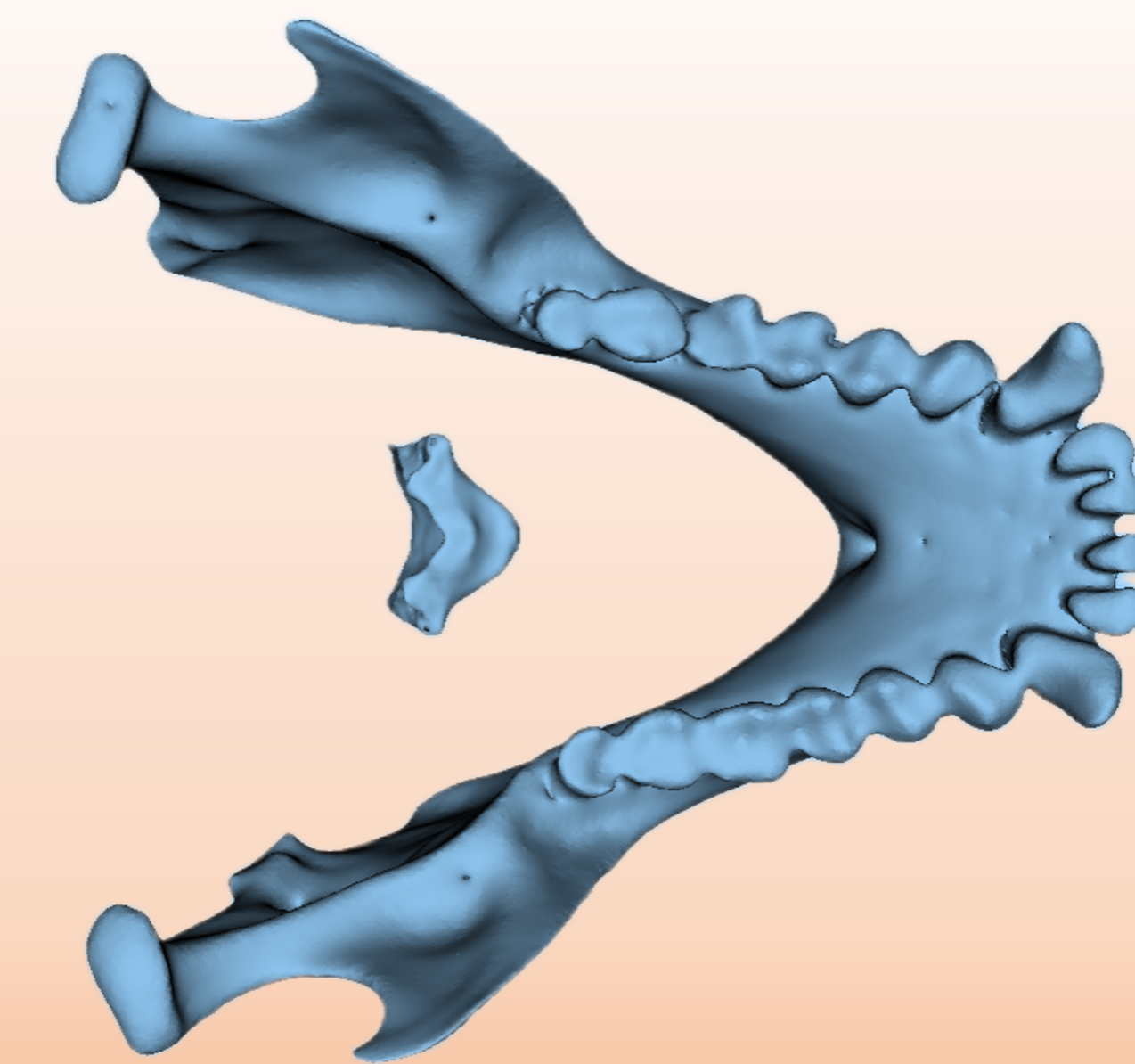


Investigating covariation between basihyal shape and the mandibular symphysis in an ontogenetic sample of tufted and untufted capuchins

Parker M. Taylor¹, Taylor A. Polvadore¹, Caitlin B. Yoakum², Janine Chalk-Wilayto³, Mariana Dutra Fogaça⁴, Megan A. Holmes⁵, Myra F. Laird⁶, Claire E. Terhune¹

¹Department of Anthropology, University of Arkansas, ²Department of Anatomy, Arkansas Colleges of Health Education, ³Department of Biomedical Sciences, Mercer University School of Medicine, ⁴Neotropical Primates Research Group – NeoPREGo, ⁵Department of Family Medicine and Community Health, Duke University, ⁶Department of Basic and Translational Science, University of Pennsylvania



INTRODUCTION: Current research on the primate hyoid apparatus suggests feeding behaviors, such as mastication and swallowing, play important roles in shaping hyoid morphology. Previous analyses of basihyal (hyoid body) shape in capuchins revealed tufted (*Sapajus spp.*) and untufted (*Cebus spp.*) capuchins possess significantly different hyoid morphologies throughout ontogeny¹. Tufted capuchins are also known to possess more robust mandibular symphyses than their untufted counterparts, which aids in resisting increased lateral transverse bending (wishboning) due to their overall more mechanically challenging diet². Because the hyoid is biomechanically linked to the mandible at the symphysis via the suprahyoid muscles, increased wishboning resistance should affect lingual mandibular morphology, and thus potentially affect the suprahyoid muscles³. Therefore, we predict hyoid shape and symphyseal cross-sectional morphology covary. **Here, we quantify the relationship between basihyal shape and mandibular symphysis morphology across ontogeny in capuchins.**

MATERIALS AND METHODS

- Basihyals were segmented from soft-tissue microCT scans of 30 *Sapajus* and 20 *Cebus* specimens in Avizo⁴. Age groups were assigned based on dental occlusion (Infants \leq dpm3, Juveniles = dpm4, Subadult = M1-M2, Adult \geq M3).
- 200 3D sliding semilandmarks placed across the surfaces of the basihyals using Auto3DGM⁵ (Fig.1)
- Sagittal CT slices of the mandibular symphysis were cleaned of trabecular bone and analyzed in ImageJ using the BoneJ plug-in⁶.
- Wishboning resistance index was calculated by dividing the moment for wishboning ($\sqrt[4]{I_{yy}}$) by mandible length² (Linear measurement from posterior edge of condyle to infradentale).
- 16 2D landmarks (2 fixed, 14 sliding semilandmarks) placed along the border of mandibular symphyses in 3DSlicer⁷ (Fig. 1).
- Geometric morphometric methods (GPA, PCA, Multivariate multiple regression, 2B-PLS) were used to compare basihyal shape and symphyseal morphology and wishboning in R⁸ and MorphoJ⁹

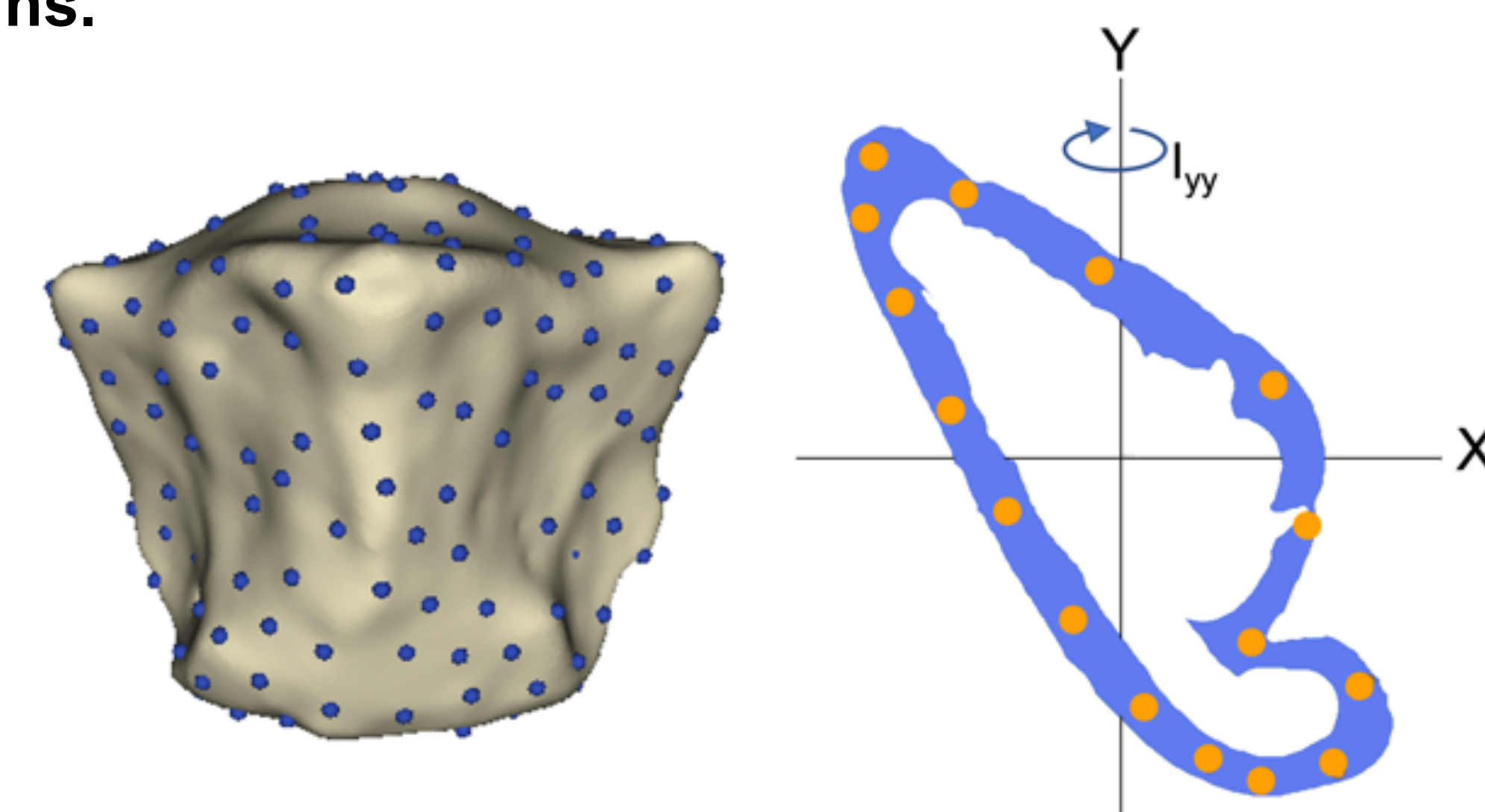


Figure 1. (Left) Anterior view of basihyal (*Cebus spp.*) with 3D surface semilandmarks and (Right) 2D sagittal slice of the cortical bone of the mandibular symphysis for the same specimen. I_{yy} represents the moment around the Y axis (wishboning) and orange circles represent 2D landmarks

RESULTS

- No significant relationship between hyoid shape and wishboning resistance at any age group (Fig. 2)**
 - Cebus*: $p = 0.556$
 - Sapajus*: $p = 0.29$
- Significant taxonomic differences in symphyseal shape in adults and subadults, but not in younger groups, with *Sapajus* possessing more pronounced simian shelves (Fig. 3).**
 - Adult: $p = 0.041$
 - Subadult: $p = 0.048$
 - Juvenile: $p = 0.051$
 - Infant: $p = 0.754$
- No significant correlations between hyoid shape and symphysis shape in either *Cebus* (Fig. 4) or *Sapajus* (Fig. 5)**

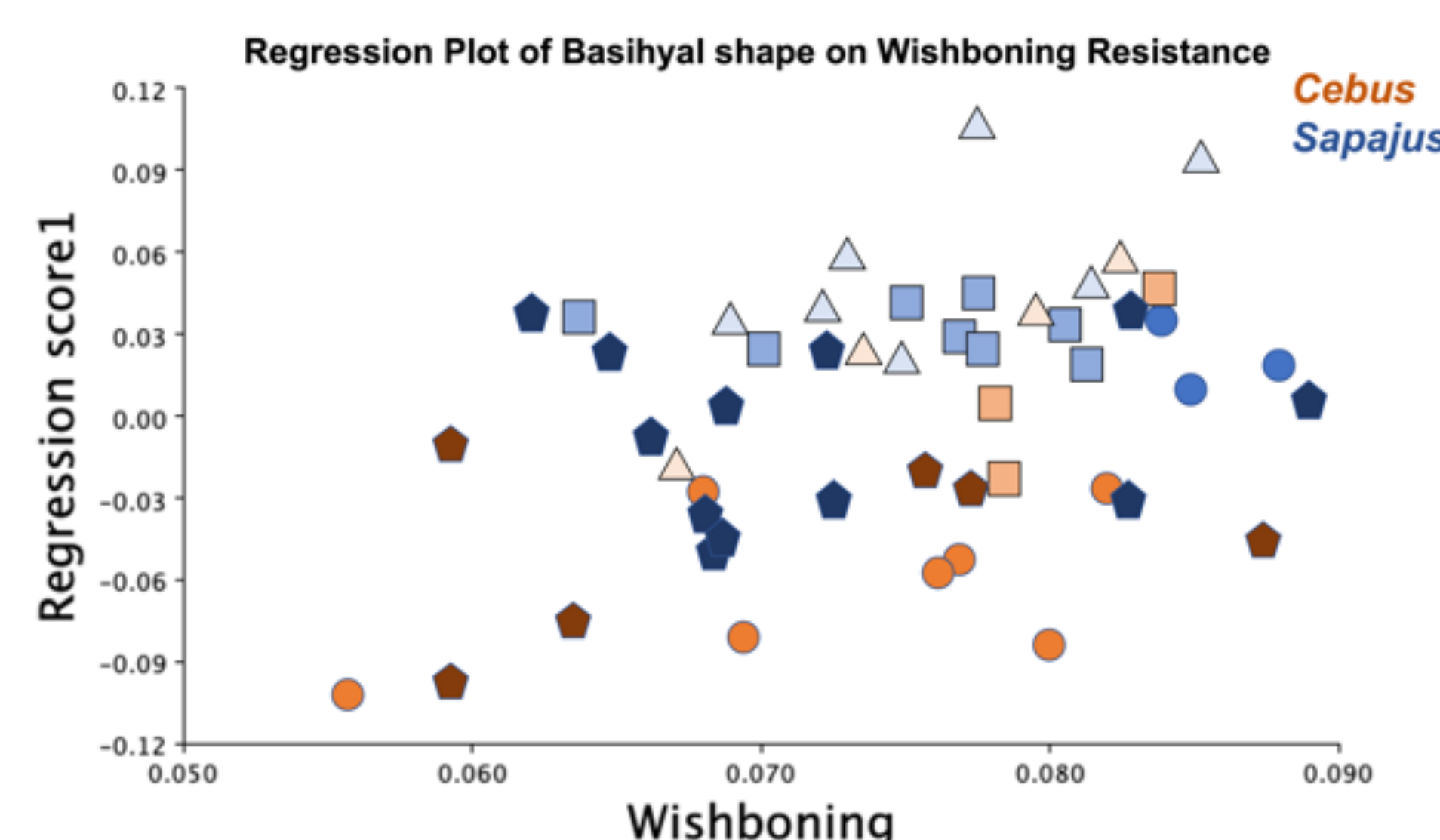


Figure 2. Bivariate plot for the regression of basihyal shape on wishboning resistance). Infants = triangles, Juvenile = square, Subadult = circles, Adults = pentagons.

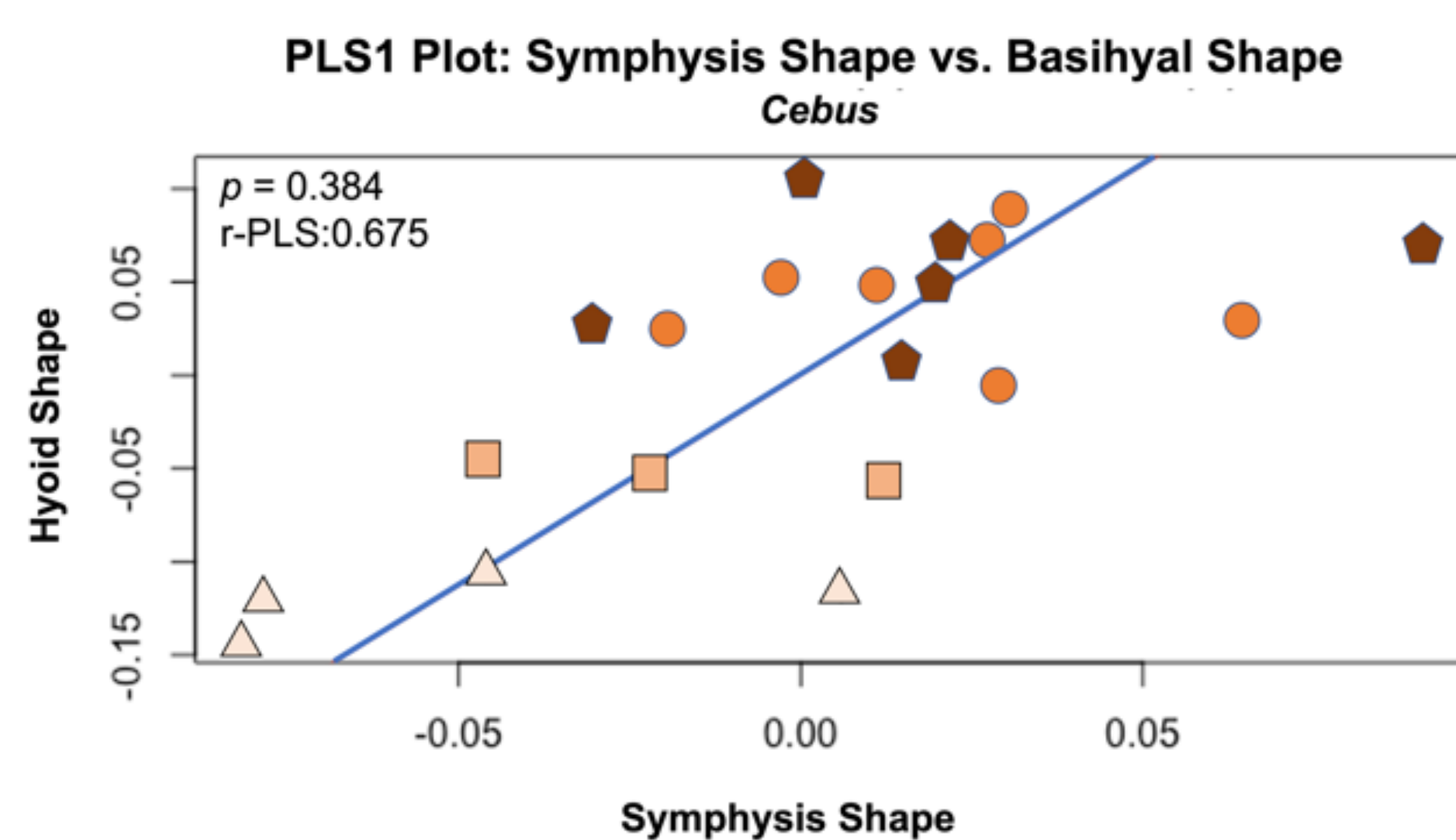


Figure 4. Bivariate plot of the partial least squares scores of the first singular vectors (PS1) of the symphysis versus the basihyal in *Cebus*. Infants = triangles, Juvenile = square, Subadult = circles, Adults = pentagons.

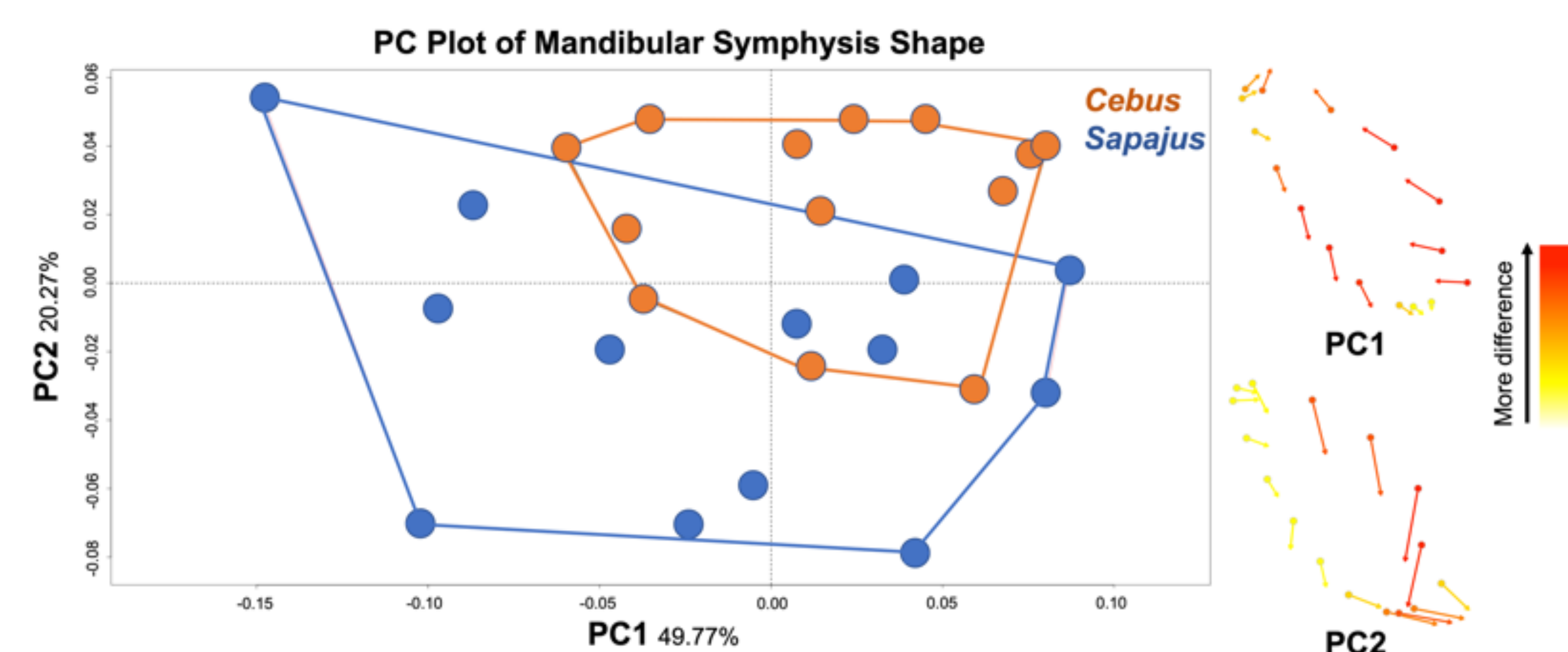


Figure 3. Bivariate plot of PC1 and PC2 for symphyseal shape showing distributions for Adult and Subadult *Cebus* and *Sapajus*. Heat-maps showing positive to negative landmark changes for both PC1 and PC2 are also included, where greater changes between landmarks are redder and fewer changes are more yellow (PC2 has been magnified x2).

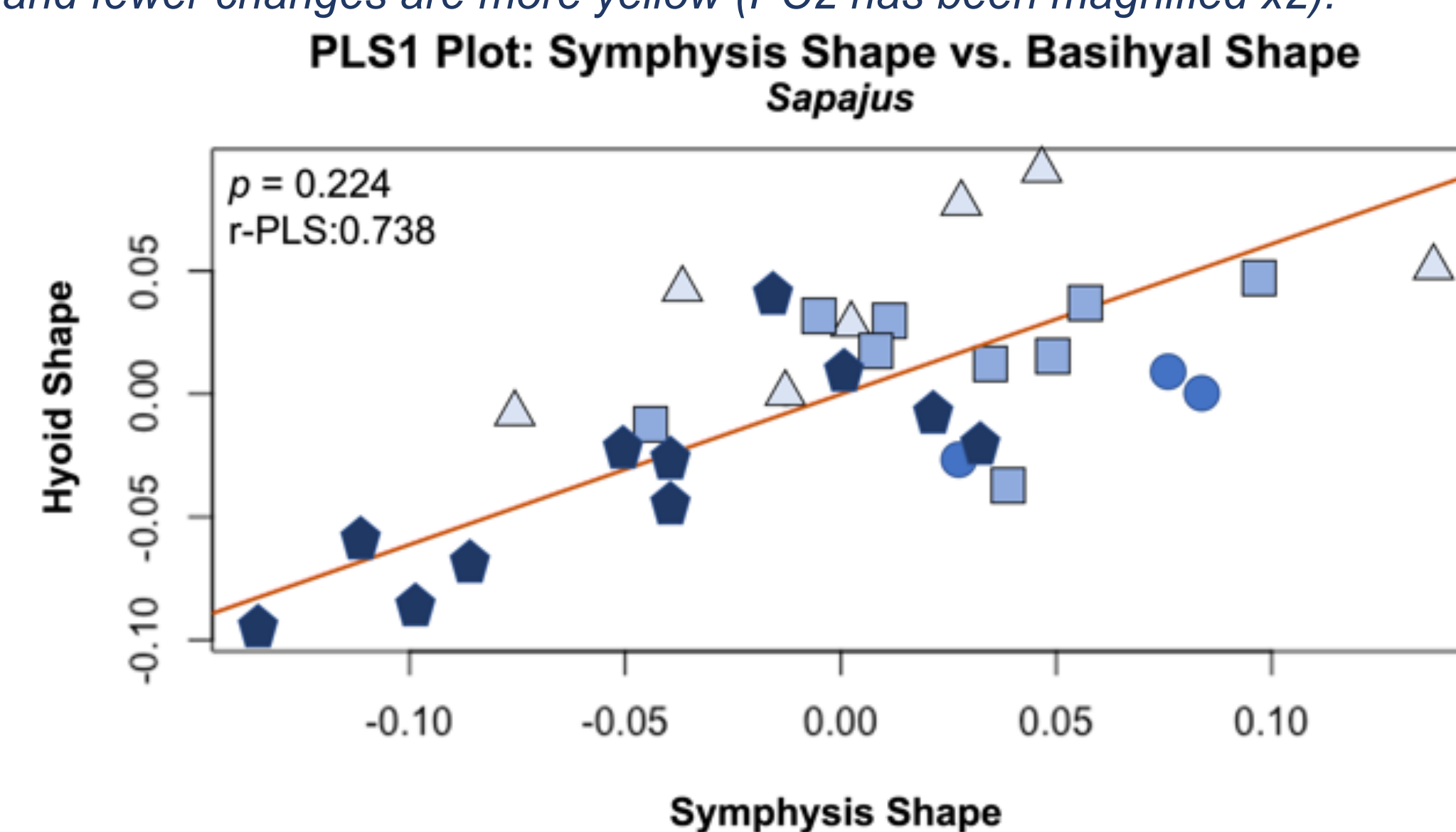


Figure 5. Bivariate plot of the partial least squares scores of the first singular vectors (PS1) of the symphysis versus the basihyal in *Sapajus*. Infants = triangles, Juvenile = square, Subadult = circles, Adults = pentagons.

DISCUSSION: Contrary to our expectations, we find no covariation between basihyal shape and symphyseal morphology across ontogeny in either *Sapajus* or *Cebus*. Such findings suggest the well-documented dietary differences between these taxa do not explain the taxonomic differences in hyoid shape. One possible explanation for this may be that intraspecific covariation between these traits may simply be too low to detect. Interspecific covariation could not be addressed here as the sample contained only two, closely-related genera. Future analyses will focus on a broader taxonomic sample to assess covariation between primate groups. Additionally, future work will include general mandibular shape and suprahyoid muscle architecture to better assess the relationship between hyoid morphology and feeding behavior. It is also worth noting that this sample likely consists of lab-kept specimens that would have been fed the same food items. It is possible that symphyseal robusticity is a plastic trait. Examining these traits in a wild sample, where dietary differences would be actualized, may yield different results.

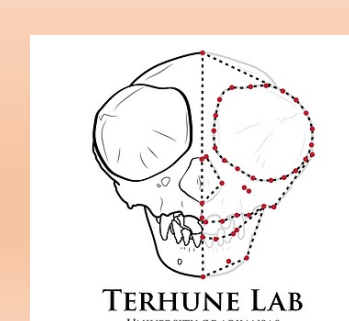


ACKNOWLEDGEMENTS: This research was supported by grants from the National Science Foundation's Biological Anthropology directorate (NSF-BCS-1945771, NSF-BCS-1944915, NSFBCS-1945283, NSF-BCS-1945767, NSF-DDRIG 1944642). Special thanks to Doug Boyer and Duke University Evolutionary Anthropology for access to these specimens, and to the Auto3dGM team for their assistance with this research. We also thank UArk MICRO (NSF-BCS-1725925) for assistance with microCT scanning.



CONTACT INFORMATION:

Parker M. Taylor, MSc.
PhD Candidate
Email: pmtaylor@uark.edu



REFERENCES: 1. Taylor et al. (2022). *Am. J. Biol. Anthropol.* 177:179. 2. Daegling (1992). *Int. J. Primatol.* 13:545-570. 3. Hylander (1984). *Am. J. Phys. Anthropol.* 64:1-46. 4. FEI. (2016). Zuse Institute Berlin. 5. Boyer et al. (2015). *Anat Rec.* 298:249-276. 6. Doube et al. (2010). *Bone* 47(6):1076-1079. 7. Fedorov et al. (2012). *Magn. Reson. Imaging* 30(9): 1323-1341. 8. R Core Team. (2021). 9. Klingenberg (2011). *Mol. Ecol. Resour.* 11:353-357