Revisiting Primate Masticatory Scaling Relationships

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Introduction

Previous work on the masticatory apparatus (e.g., Bouvier, 1986a,b; Hylander, 1985; Jungers et al., 1995) has demonstrated unique scaling patterns in the temporomandibular joint (TMJ) and mandible of both platyrrhines and cercopithecoids that can be linked to dietary behaviors. For example, folivory and ingestion of large, tough fruits in cercopithecoids (Bouvier, 1986b; Smith et al., 1983) has been demonstrated to be positively correlated with their deeper mandibles and wider condyles. However, these adaptations are not shared by folivorous platyrrhines (Bouvier, 1986a), suggesting a phylogenetic component to the observed variation. Notably, these studies did not take into account the phylogenetic relationships among species, did not include hominoids (and assessed cercopithecines and platyrrhines separately), and only evaluated males or females without consideration of both sexes. Females were initially analyzed separately from males in Bouvier (1986a:553) but were removed when it was concluded that "few statistically significant differences were found between the scaling patterns of the two sexes". In this study, we analyze a broad sample of anthropoid primates to determine the role of phylogeny and sexual dimorphism in masticatory scaling.

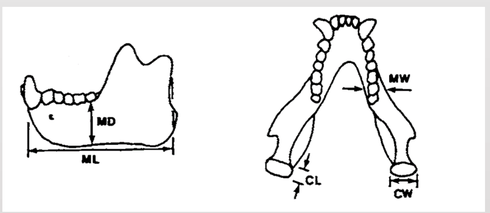
Research Questions

In this study we examined the following questions

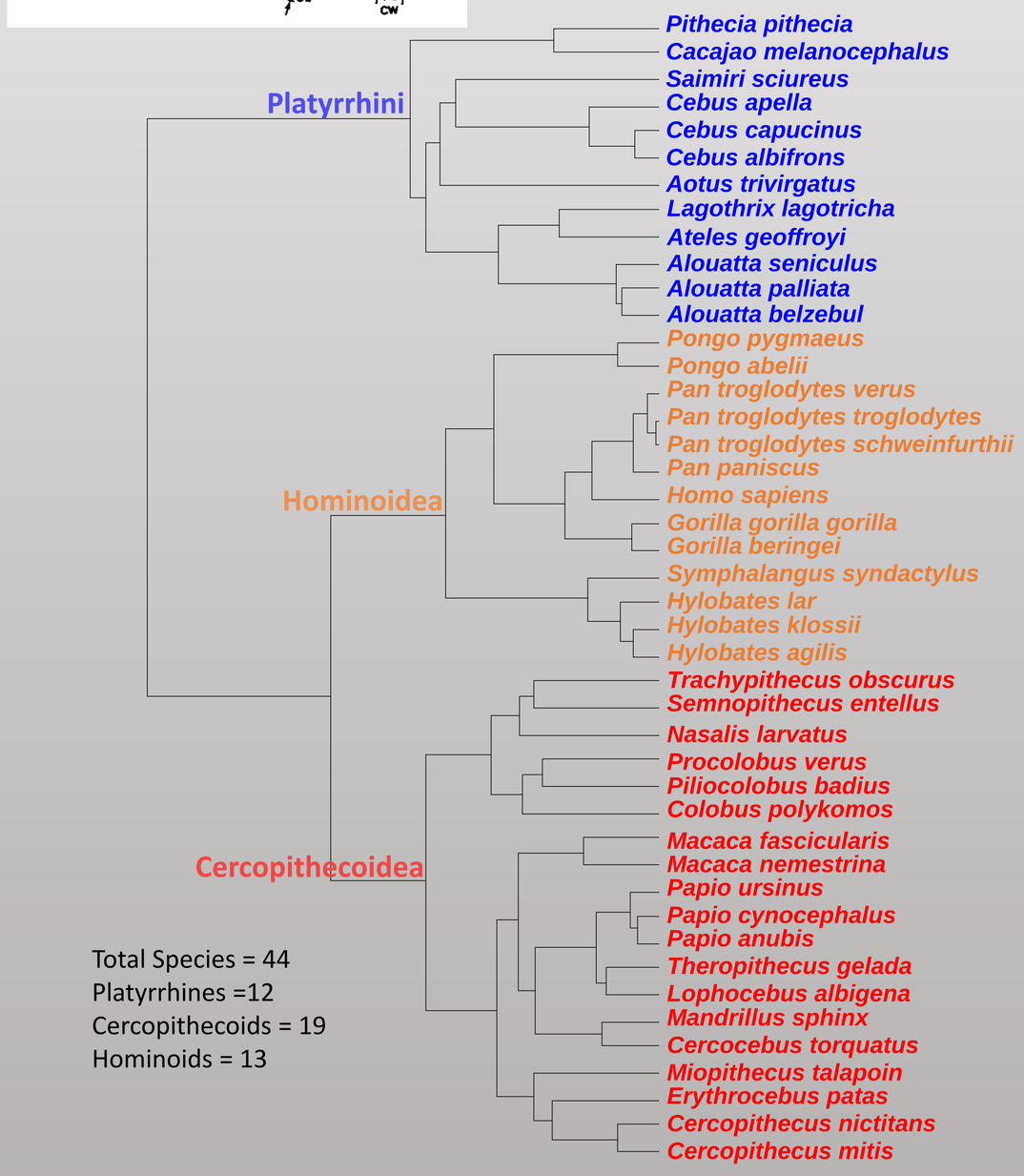
1. Are the data phylogenetically patterned and how are the results affected when statistically accounting for phylogeny?
2. Do masticatory scaling patterns differ in males and females?
3. How do scaling patterns differ among platyrrhines, cercopithecoids, and hominoids?

Materials

- Mean species/sex body mass drawn from Smith and Jungers (1997)
- Condylar and mandibular measurements from Terhune (2010)



Measurements of the mandible utilized by Bouvier (1986a) and employed here.



Total Species = 44
Platyrrhines =12
Cercopithecoids = 19
Hominoids = 13

Methods

- RMA regressions (Smith, 2009) of condyle and corpus measurements against both mandible length (as a measure of the masticatory lever arm)and body mass (as an indicator of the overall size of the animal) (i.e., Hylander, 1985; Vinyard, 2008)
- Males and females were analyzed separately; analyses were initially performed on all taxa and then for platyrrhines, cercopithecoids, and hominoids separately
- All data were log transformed for analysis

Results

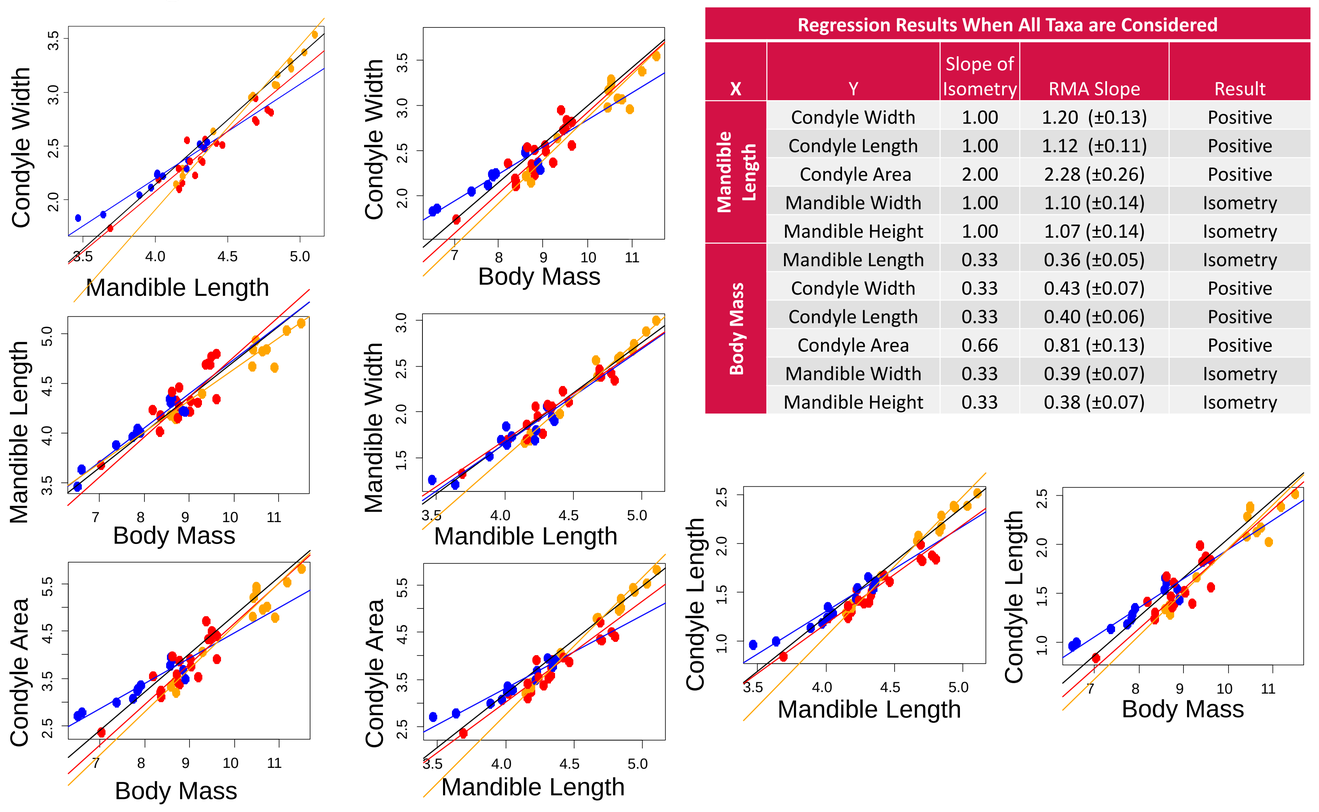
- All regressions were significant ($p<0.0016$) with $r^2>0.741$ (all taxa) or $r^2>0.65$ (clades separated)
- A strong phylogenetic signal was found for most relationships
- Condylar variables (length, width, area) tend to be positively allometric, whereas mandibular measurements were more likely to scale with isometry

Λ*, Strength of the phylogenetic signal approximated 0-1

Sex	X	Y	All	Platy.	Cerco.	Hom.
Female	Mandible Length	Condyle Width	0.91	0.00	0.67	0.00
		Condyle Length	0.86	0.00	0.00	0.00
		Condyle Area	0.92	0.31	0.42	0.00
		Mandible Width	1.00	0.00	0.85	1.00
		Mandible Height	0.99	1.00	0.00	1.00
	Body Mass	Mandible Length	0.95	1.00	1.00	0.90
		Condyle Width	0.87	0.92	0.74	0.00
		Condyle Length	0.87	0.83	0.83	0.63
		Condyle Area	0.89	0.88	0.76	0.51
		Mandible Width	0.96	1.00	1.00	0.56
		Mandible Height	0.95	1.00	1.00	0.69
Male	Mandible Length	Condyle Width	0.95	0.00	0.71	0.00
		Condyle Length	0.90	0.00	0.00	0.00
		Condyle Area	0.95	0.00	0.59	0.00
		Mandible Width	0.99	1.00	1.00	1.00
		Mandible Height	1.00	1.00	0.98	1.00
	Body Mass	Mandible Length	0.92	0.97	0.94	0.00
		Condyle Width	0.76	0.91	0.70	0.00
		Condyle Length	0.87	1.00	0.81	0.00
		Condyle Area	0.86	1.00	0.77	0.00
		Mandible Width	0.91	1.00	0.97	0.00
		Mandible Height	0.92	0.82	0.89	0.43

*a value of 0 signifying no signal, 1 signifying a strong signal

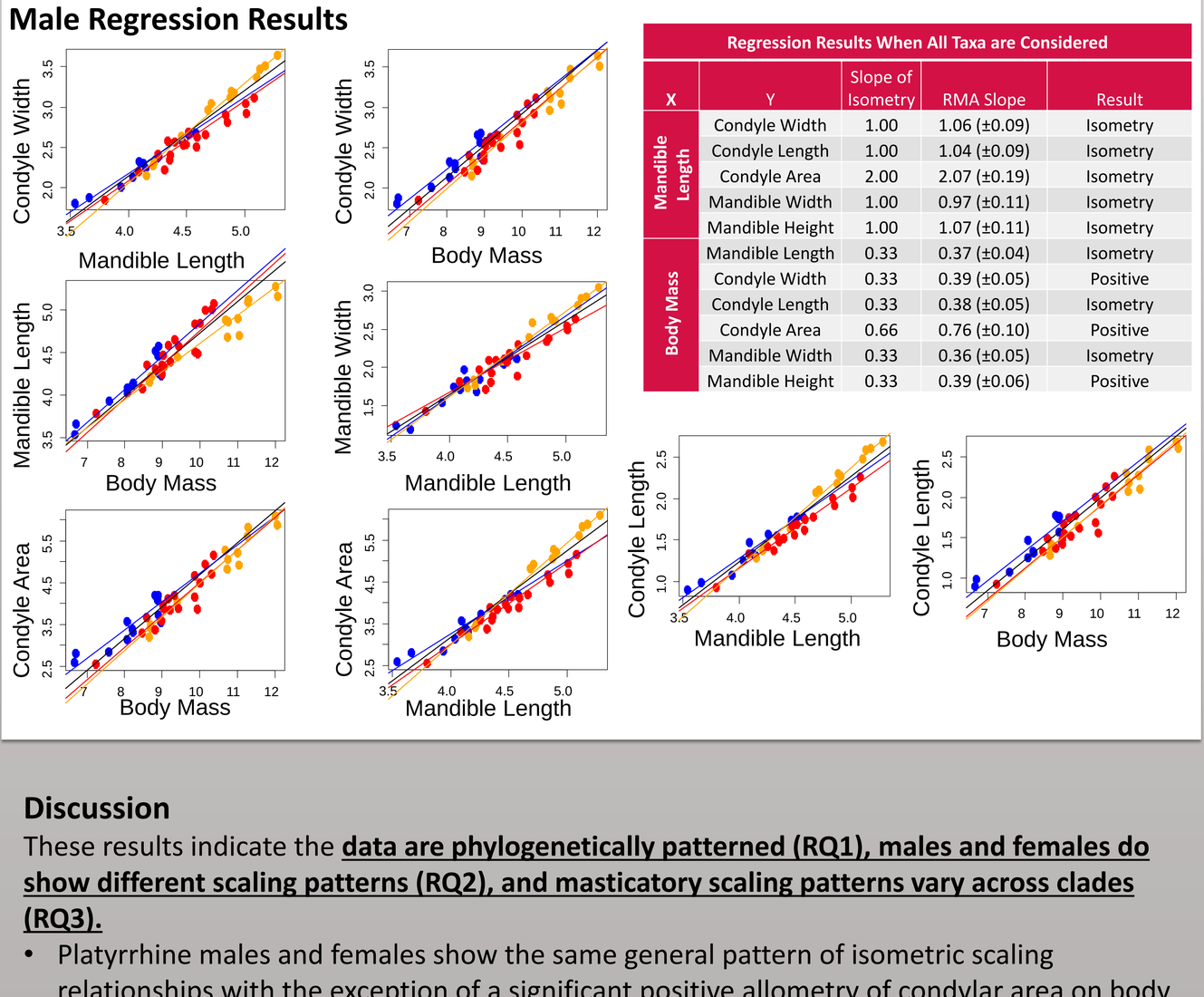
Female Regression Results



Regression Results When All Taxa are Considered

X	Y	Slope of Isometry	RMA Slope	Result
Mandible Length	Condyle Width	1.00	1.20 (±0.13)	Positive
	Condyle Length	1.00	1.12 (±0.11)	Positive
	Condyle Area	2.00	2.28 (±0.26)	Positive
	Mandible Width	1.00	1.10 (±0.14)	Isometry
	Mandible Height	1.00	1.07 (±0.14)	Isometry
Body Mass	Mandible Length	0.33	0.36 (±0.05)	Isometry
	Condyle Width	0.33	0.43 (±0.07)	Positive
	Condyle Length	0.33	0.40 (±0.06)	Positive
	Condyle Area	0.66	0.81 (±0.13)	Positive
	Mandible Width	0.33	0.39 (±0.07)	Isometry
	Mandible Height	0.33	0.38 (±0.07)	Isometry

Male Regression Results



Regression Results When All Taxa are Considered

X	Y	Slope of Isometry	RMA Slope	Result
Mandible Length	Condyle Width	1.00	1.06 (±0.09)	Isometry
	Condyle Length	1.00	1.04 (±0.09)	Isometry
	Condyle Area	2.00	2.07 (±0.19)	Isometry
	Mandible Width	1.00	0.97 (±0.11)	Isometry
	Mandible Height	1.00	1.07 (±0.11)	Isometry
Body Mass	Mandible Length	0.33	0.37 (±0.04)	Isometry
	Condyle Width	0.33	0.39 (±0.05)	Positive
	Condyle Length	0.33	0.38 (±0.05)	Isometry
	Condyle Area	0.66	0.76 (±0.10)	Positive
	Mandible Width	0.33	0.36 (±0.05)	Isometry
	Mandible Height	0.33	0.39 (±0.06)	Positive

Discussion

These results indicate the **data are phylogenetically patterned (RQ1), males and females do show different scaling patterns (RQ2), and masticatory scaling patterns vary across clades (RQ3).**

- Platyrrhine males and females show the same general pattern of isometric scaling relationships with the exception of a significant positive allometry of condylar area on body mass in females.
- Cercopithecoids demonstrated more variation between males and females than platyrrhines. Notably, in cercopithecoid males mandible width vs. mandible length was negatively allometric while females demonstrated isometry. Males cercopithecoids demonstrated positive allometry in mandible height on body mass.
- Hominoids primarily scale with positive allometry, with strong positive allometry in condylar width, length, and area in females and condylar area in males.

Our results suggest that the previous analysis (Bouvier, 1986a,b), though sufficient at the time, can be improved upon by incorporating phylogenetic methods as well as including hominoids and females. These revised analyses indicate that masticatory scaling patterns vary considerably across sexes and clades, potentially in relation to dietary or other behavioral differences.

Literature Cited

Bouvier M. 1986a. Int J Prim 7: 551-567
Bouvier M. 1986b. AJPA 69 :473-482 Hylander W. 1985. Am Zool 25:315-330
Smith RJ. 2009. AJPA 140: 476-486
Smith J, Jungers W. 1997. JHE 32:523-559 Terhune C. 2010. Ph.D. Diss, ASU
Vinyard C. 2008. In: Prim Craniofac Func Biol, pp. 357-385

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