Mandibular correlates of somatic growth in African apes

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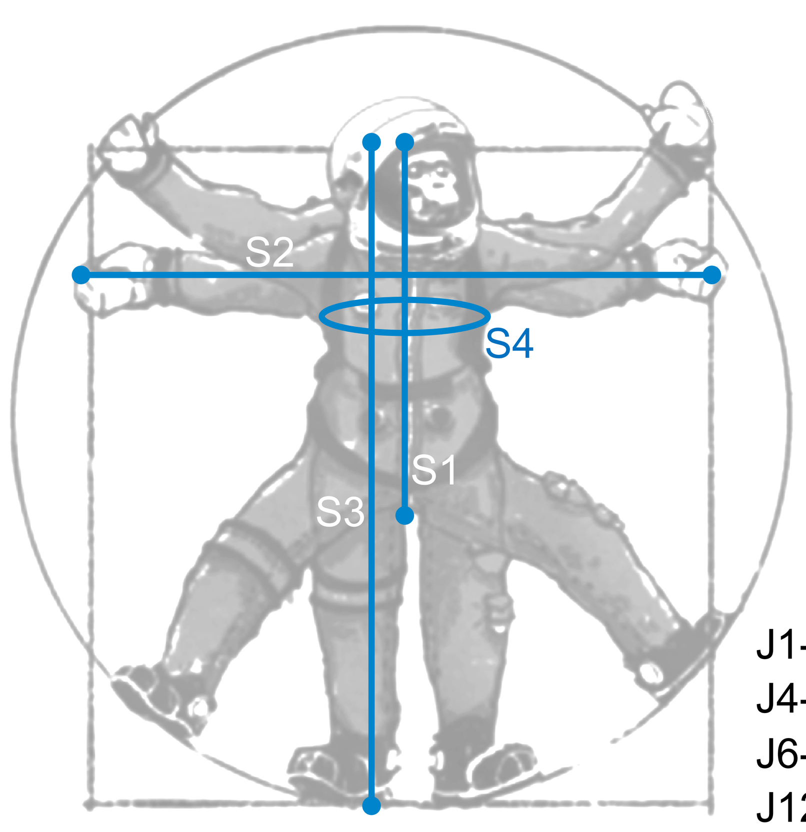
BACKGROUND & RATIONALE

- Building off Alan Mann's pioneering work on dental development in South African australopithecines, this study seeks to identify mandibular dimensions that can be used to infer bodily growth in fossil taxa.
- Body size growth is an important life history variable, but it is problematic to reconstruct in extinct species because of limited ontogenetic series of postcrania.
- Mandibles may provide an alternate source of information about somatic growth, since jaws are relatively abundant, and dental development/eruption provide some indication of age or stage of maturation.
- Many studies have identified craniodental correlates of body size in adult primates, but such relationships have not been examined across the growth period.
- Here, I examine correlation and allometry of somatic and mandibular dimensions in chimpanzees (*Pan troglodytes*) and gorillas (*Gorilla gorilla*).
- If any mandibular traits correlate and scale with body size the same way in both species across the growth period, these may make good candidates for reconstruction of body size growth in fossil hominins.

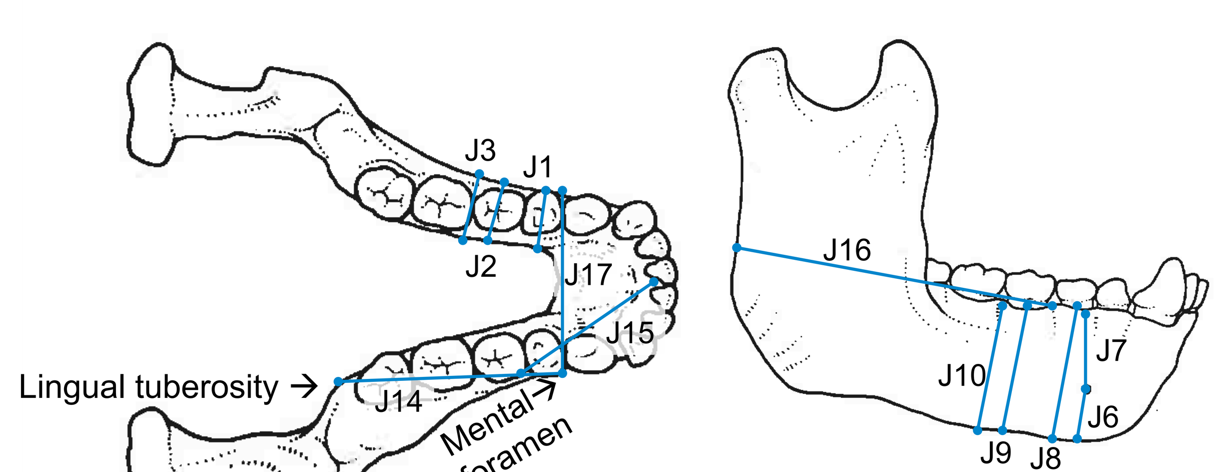
DATA

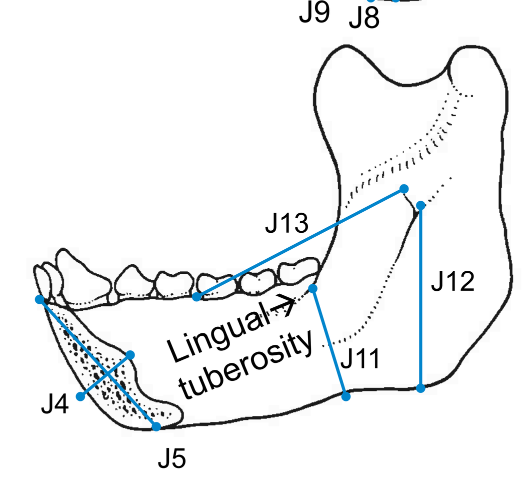
- Specimens are wild-shot from the Powell Cotton (Quex) museum in Kent, UK.
- Somatic dimensions (S1-4) were taken by naturalists in the field upon specimen death.
- Mandibular dimensions (J1-17) were collected by the author. Measurements are likely to be found in fossil fragments.
- Variables were $\log_{10}$ transformed for analysis.

Eruption stage	*Pan troglodytes* (n)	*Gorilla gorilla* (n)
1: Deciduous only	3	5
2: M1 occluded	12	8
3: M2 occluded	13	6
4: M3 erupting	3	3
5: M3 occluded	7	8
Total	**38**	**30**



S1: Head+trunk
S2: Arm span
S3: Stature
S4: Chest girth

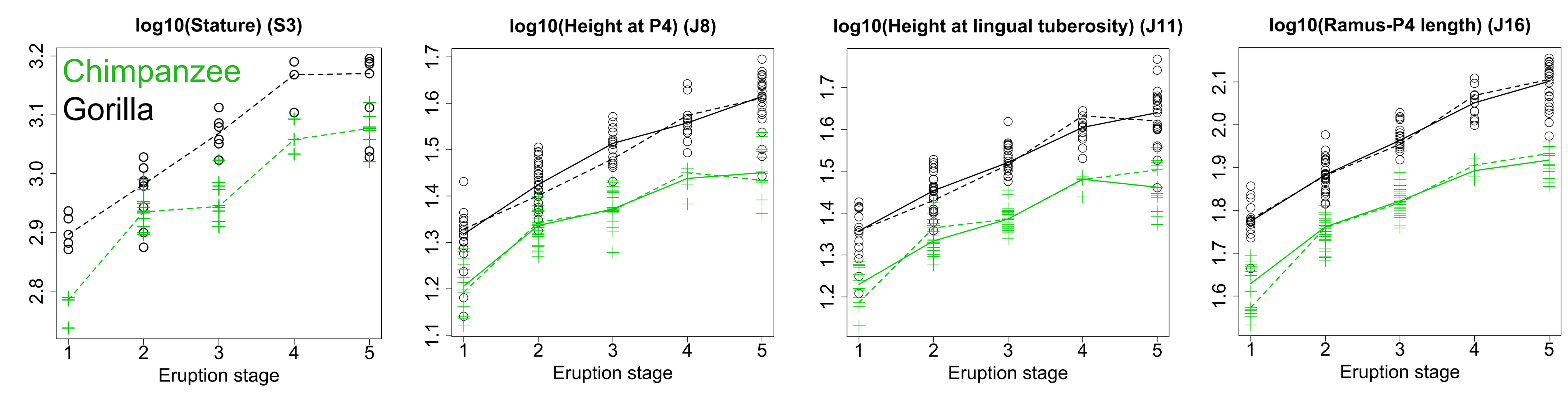




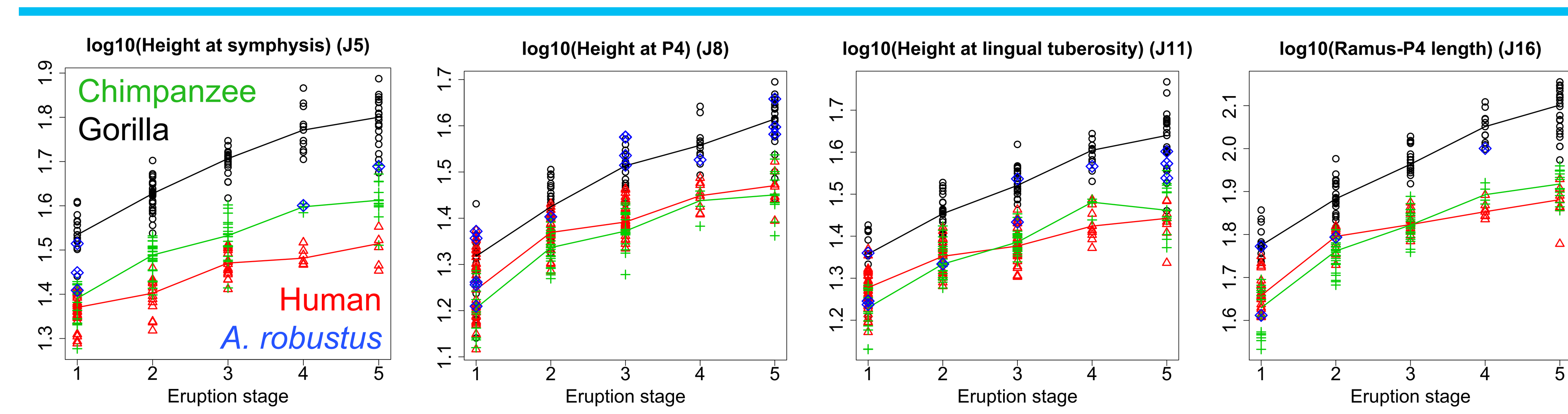
J1-3: Corpus breadth
J4-5: Symphysis height and breadth
J6-11: Corpus height
J12, 16: Ramus height and length
J13-15: Corpus length
J17: Bi-mental breadth

GROWTH IN HOMININS

- Traits that are both highly correlated and scale isometrically with body size in both species make good candidates for traits that can be used to reconstruct body growth in the absence of postcranial fossils.
- Corpus heights are ideal (i.e., J5, J8 and J11): they preserve often in fossil and archaeological samples, they correlate fairly highly with body dimensions, and they tend to scale isometrically with the body.
- Corpus and ramus lengths are also ideal (i.e., J13 and J16): they correlate most highly of all, but tend to scale with positive allometry.
- Figures below compare mandibular growth for these ideal measurements, in larger samples of gorillas (n=97), chimpanzees (82), humans (n=129) and the fossil hominin *Australopithecus robustus* (n=17).



Stature (S3) compared with three mandible dimensions across the growth period. The lines connect median values for each eruption stage. Somatic data for the left plot are available for 38 chimpanzees and 30 gorillas, while the right three plots include these apes (medians connected by dashed lines), as well as the rest of the Powell Cotton apes without somatic data (medians connected by solid lines). Note how closely the median trends for mandibular traits in the smaller somatic sample (dashed lines) track those for stature.



Comparison of growth in four mandibular traits between gorillas, chimpanzees, humans, and *Australopithecus robustus*. The human pattern of bodily growth, with a slow juvenile phase (before eruption stage 3) and accelerated growth at adolescence (stages 3-4), has been linked to our unique adaptive strategy involving language and culture. This pattern is only apparent for corpus height at P_4 (J8), and even then chimpanzees show a similar pattern, if not an even more marked adolescent 'spurt.' Whether this reflects true growth patterns in these populations, or is an artifact of sample sizes remains to be determined. Nevertheless, where *A. robustus* can be compared to living species, its values tend to fall in the gorilla range, suggesting consistently high bodily growth rates. Mann's landmark study showed human-like dental development in *A. robustus*, and the present findings suggest this may have been complimented by rapid gorilla-like body growth.

MANDIBLE – BODY CORRELATION COEFFICIENTS

		Pan				*Gorilla*			
	Trait	S1	S2	S3	S4	S1	S2	S3	S4
Corpus Breadth	J1	0.82	0.85	0.80	0.81	0.91	0.89	0.85	0.89
	J2	0.60	0.59	0.60	0.55	0.66	0.64	0.66	0.67
	J3	0.26	0.31	0.24	0.22	0.42	0.43	0.48	0.50
Symphysis breadth and height	J4	0.78	0.78	0.79	0.71	0.90	0.90	0.90	0.90
	J5	0.89	0.90	0.86	0.87	0.96	0.95	0.94	0.94
Corpus height	J6	0.78	0.80	0.80	0.79	0.84	0.86	0.84	0.89
	J7	0.86	0.83	0.82	0.81	0.80	0.73	0.77	0.71
	J8	0.90	0.88	0.86	0.88	0.94	0.94	0.92	0.93
	J9	0.89	0.87	0.83	0.87	0.96	0.94	0.91	0.93
	J10	0.80	0.81	0.77	0.73	0.92	0.88	0.83	0.90
	J11	0.92	0.92	0.93	0.86	0.93	0.92	0.92	0.92
Ramus height	J12	0.78	0.91	0.79	0.91	0.95	0.95	0.96	0.96
Corpus length	J13	0.93	0.96	0.94	0.95	0.96	0.97	0.95	0.97
	J14	0.88	0.92	0.89	0.91	0.95	0.95	0.96	0.96
	J15	0.82	0.87	0.82	0.84	0.92	0.91	0.92	0.91
Ramus length	J16	0.96	0.97	0.94	0.95	0.98	0.98	0.96	0.96
Bi-mental breadth	J17	0.78	0.81	0.81	0.83	0.87	0.88	0.86	0.86

R: <0.50, <0.70, <0.80, <0.85, <0.90, <0.95

- Correlations between mandibular and somatic traits were calculated in the program R.
- Overall patterns of mandible-body correlations are similar between species, but correlations are generally higher in *Gorilla* than in *Pan*.
- For *Pan*, correlations are highest on average for S1 and S2, versus S1 and S4 for *Gorilla*.
- Ramus length (J16) is most highly correlated with somatic traits in both species, followed by the length from the mandibular foramen to the lingual $P_{3\text{-}4}$ septum (J13)
- Symphysis (J5) and corpus heights (J8 and J11) also have relatively high correlations in both species.

MANDIBLE – BODY REGRESSION SLOPES

	Pan				*Gorilla*			
Trait	S1	S2	S3	S4	S1	S2	S3	S4
J1	0.57	0.57	0.55	0.44	0.59	0.62	0.66	0.58
J2	0.31	0.31	0.29	0.24	0.36	0.37	0.40	0.37
J3	0.34	0.40	0.36	0.30	0.35	0.34	0.34	0.31
J4	0.80	0.72	0.75	0.53	0.83	0.83	0.88	0.78
J5	0.96	0.94	0.96	0.71	1.03	0.96	1.02	0.89
J6	0.87	0.75	0.80	0.53	1.08	1.07	1.14	1.04
J7	0.95	0.96	0.95	0.77	0.73	0.66	0.70	0.63
J8	0.95	0.88	0.94	0.70	1.00	0.99	1.05	0.91
J9	1.03	1.02	1.06	0.78	1.07	1.13	1.13	0.95
J10	0.97	1.04	0.98	0.76	1.12	1.15	1.17	1.03
J11	1.04	0.92	0.99	0.72	1.06	1.03	1.10	0.96
J12	1.15	1.22	1.11	0.99	1.31	1.22	1.32	1.14
J13	1.41	1.31	1.37	1.02	1.36	1.28	1.36	1.15
J14	1.29	1.03	1.24	0.72	0.94	0.85	0.90	0.82
J15	0.43	0.45	0.43	0.34	0.61	0.54	0.58	0.50
J16	1.18	1.08	1.14	0.83	1.11	1.07	1.15	0.96
J17	0.60	0.56	0.58	0.41	0.63	0.61	0.65	0.53

Slope: NEGATIVE ALLOMETRY / ISOMETRY / POSITIVE ALLOMETRY

- Reduced major axis regression of each mandibular trait against each somatic trait was performed using the lmodel2 package (Legendre 2012) for R.
- Slopes whose 95% confidence intervals contain 1 mean that isometry (1:1) cannot be rejected.
- In both species, head+trunk length (S1) has the most isometrically scaling mandibular traits.
- Negative allometry is fairly common and positive allometry fairly rare in both species.
- Corpus heights (J8-11) and symphysis height (J5) scale isometrically with all somatic dimensions in both species, except for chest girth (S4) in *Pan*.

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Resources

Statistics: R (R Core Team, 2013; http://www.r-project.org/). lmodel2 program and guide by Pierre Legendre (http://cran.r-project.org/web/packages/lmodel2/vignettes/mod2user.pdf)
Powell Cotton ape collection: Human Origins Database, by Adam Gordon and Bernard Wood (humanoriginsdatabase.org)