

A 3D quantitative comparative analysis of scaphoid and lunate morphology among western and eastern gorillas

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Introduction

Gorilla Geography

- Gorillas are the second closest living relative of humans
- Gorillas are distributed discontinuously across central Africa, with distinct populations living in both the west and east
- Genetic evidence suggests that eastern and western gorillas began diverging from one another between 1 and 2 million years ago (Scally et al., 2012; Thallman et al., 2007)

Gorilla Cladogram

- Eastern gorillas are divided into two subspecies: mountain (*G. b. beringei*) and grauer (*G. b. graueri*)
- Gorillas of western Africa (*G. gorilla*) differ behaviorally (e.g., more frugivorous, more arboreal) from those in eastern Africa (*G. beringei*) (e.g., more folivorous, less arboreal) (Remis, 1998)
- These behavioral differences are directly related to ecology, as western gorillas live in lowland habitats (< 1,000 m asl) (i.e., more fruits, more continuous forest) whereas eastern gorillas typically live in highland habitats (> 1,500 m asl) (Remis, 1998)

- Although all gorillas are mainly terrestrial knuckle-walking quadrupeds (Richmond et al., 2001), research has shown that foot morphology differs significantly between western and eastern gorillas, and that these differences are related to those found in climbing frequencies (Tocheri et al., 2011, Dunn et al., in press)
- Here for the first time, we examine wrist morphology among gorillas in order to test whether eastern and western gorillas differ from one another in similar ways as they do in their feet**

Gorilla Hand and Wrist

- The scaphoid and lunate bones (shown on left) form part of the two major joints in the wrist, the **radio-carpal joint** and the **mid-carpal joint**, both of which are important for determining wrist mobility
- While knuckle-walking limits the range of wrist mobility (particularly in extension) (Richmond et al., 2001), western gorillas may show adaptations for climbing in terms of a more mobile wrist in comparison to their eastern counterparts

Research Questions

Does gorilla wrist morphology vary in predictable ways according to known ecological and behavioral differences among gorillas?

Specifically, do gorillas that climb more frequently (i.e. western gorillas) have more mobile radio-carpal and mid-carpal joints than their less arboreal counterparts (i.e. eastern gorillas)?

If they vary in other ways, are these plausibly related to different frequencies of arboreality among gorillas or are they more likely related to the effects of genetic drift?



Materials and Methods

- 3D models of gorilla wrist bones were acquired using laser scanning
- These digital models were cleaned and segmented into articular and non-articular surfaces using Geomagic software
- Angles between articular surfaces, relative surface areas, and curvatures of articular surfaces were quantified using published methods (Tocheri et al., 2011)
- Canonical variates and discriminant analyses were performed using SAS 9.1 and box plots using PAST

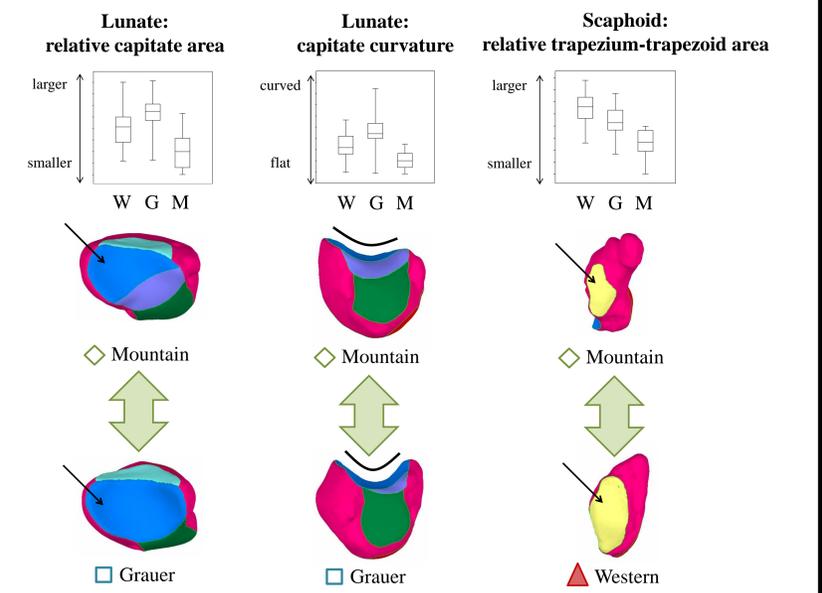
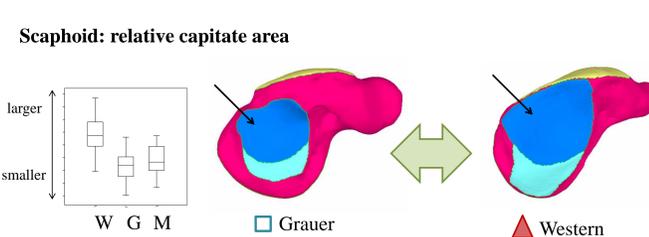
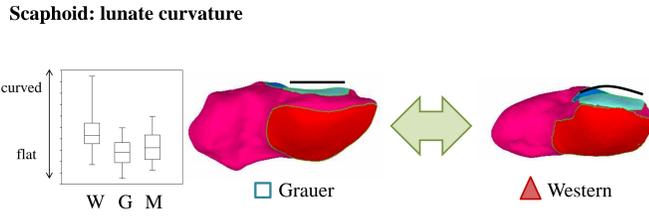
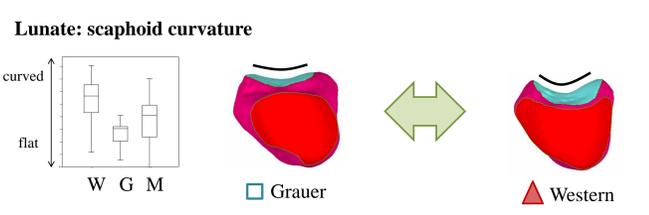
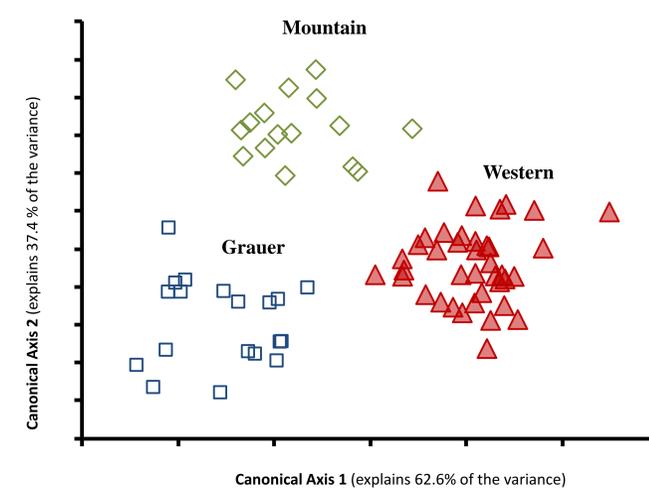
Sample Size (n)

	Lunate	Scaphoid
Western	39	40
Grauer	19	25
Mountain	16	16
Total	74	81

Results

Canonical Variates Analysis (CVA) Plot

This statistical analysis examines all 27 variables simultaneously and reduces the multi-dimensional space into two dimensions that best explain 100% of the variance



Discriminant Analysis Results

This shows how many individuals are classified as the correct taxon based on the posterior probabilities of group membership

	Crossvalidation			Resubstitution		
	Western	Grauer	Mountain	Western	Grauer	Mountain
Western	37	1	1	39	0	0
%	94.9	2.6	2.6	100	0	0
Grauer	1	17	1	0	19	0
%	5.3	89.5	5.3	0	100	0
Mountain	3	1	12	0	0	16
%	18.8	6.3	75.0	0	0	100

Discussion

- On both bones, the radial articular surfaces do not significantly differ among gorillas in angles, relative areas, or curvatures, suggesting radio-carpal joint morphology is conserved among gorillas
- Several variables that differ significantly among gorillas have plausible functional implications for wrist mobility vs. stability at the mid-carpal joint:
 - relative capitata area (scaphoid) is largest in western gorillas, suggesting a more mobile mid-carpus
 - the capitata facet (lunate) is flattest in mountain gorillas, suggesting a more stable mid-carpus
 - the scaphoid-lunate facets are more curved in western gorillas and flatter in eastern gorillas, which may allow for a more mobile mid-carpal joint in the more arboreal western gorillas
 - relative trapezium-trapezoid area (scaphoid) is largest in western gorillas, which may suggest greater use of the thumb while climbing (e.g., grasping larger supports)
- While not all of the differences observed have clear functional implications, gorilla taxa are reliably distinguishable from one another based on scaphoid and lunate morphology**
- Future studies should examine the six remaining bones that form the gorilla wrist to provide a more complete picture of wrist variation, functional morphology, and evolution in gorillas

References

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