# Locomotor variability in Sterkfontein Member 4: Analysis of the external shape and internal bone structure of the StW 562 and StW 595 first metatarsals

Zewdi J. Tsegai[1,2], Piers Gardner[2], Benjamin Chamberlain[3], Jeremy M. DeSilva[4], Bernhard Zipfel[5], Tracy L. Kivell[1,2,6], Matthew M. Skinner[1,2,6]

[1] Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, [2] School of Anthropology and Conservation, University of Kent, [3] Centre for Anatomical and Human Sciences, University of York, [4] Department of Anthropology, Dartmouth College, [5] Evolutionary Studies Institute, University of the Witwatersrand, [6] Centre for the Exploration of the Deep Human Journey, University of the Witwatersrand

## Introduction

- It remains contested whether the morphological diversity of the craniodental and postcranial hominin fossils from Member 4 of Sterkfontein can be attributed to a single taxon, *Au. africanus*[1-4].
- Variability among these fossils could be explained by intraspecific variability, temporal changes in an evolving lineage, sexual dimorphism or taxonomic diversity. With postcranial elements, this variability may indicate functional diversity.
- Two first metatarsals (Mt1) from Sterkfontein (StW 595 and StW 562) differ in their external shape[4], and here we report further analysis of the external morphology using geometric morphometrics and their internal trabecular and cortical structure.

**AIM: Explore external and internal morphology of StW 595 and StW 562 Mt1s**

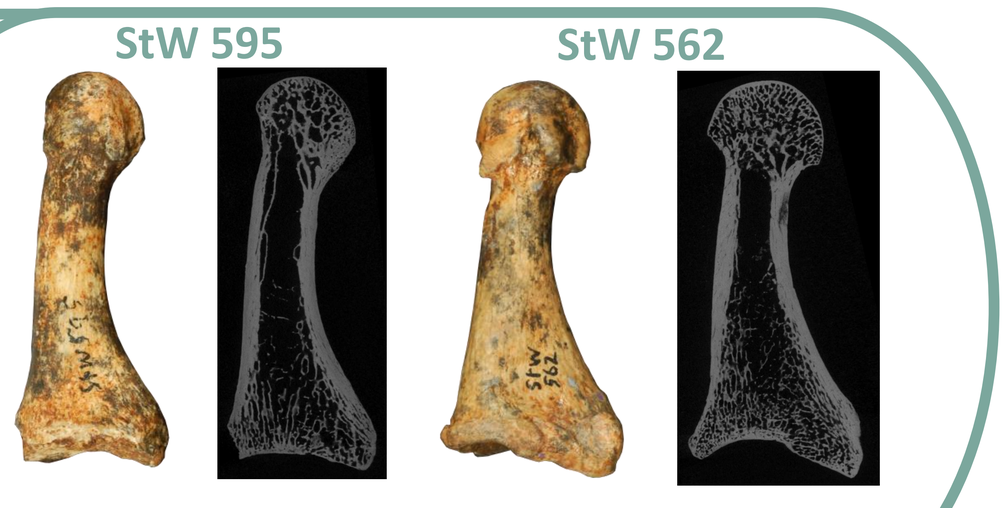


**Figure 1.** StW 595 and StW 562 first metatarsals, including images from micro-CT scans showing internal preservation

## External Shape – GM Analysis

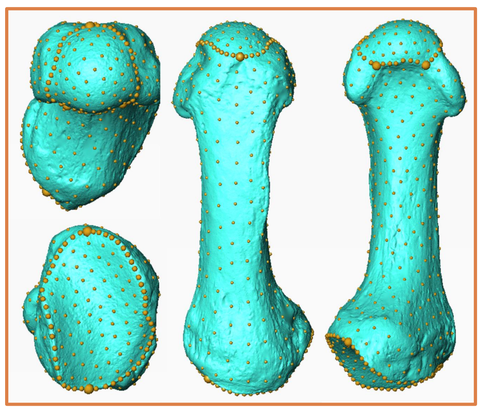

**Figure 2.** Landmark set showing both fixed and sliding curve and surface semi-landmarks

- The three fossils StW 562, StW 595 and SKX 5017 (*P. robustus*) are intermediate between the extant apes and humans
- Negative PC1 scores are associated with:
  - dorsoplantarly tall and flat proximal articular surface
  - low Mt1 shaft curvature
  - dorsally domed and mediolaterally expanded Mt1 head.

- The GM analysis **supports previous descriptions of the differing morphology of StW 595 and StW 562**[4], offering a quantitative comparison of the morphology of the entire metatarsal.

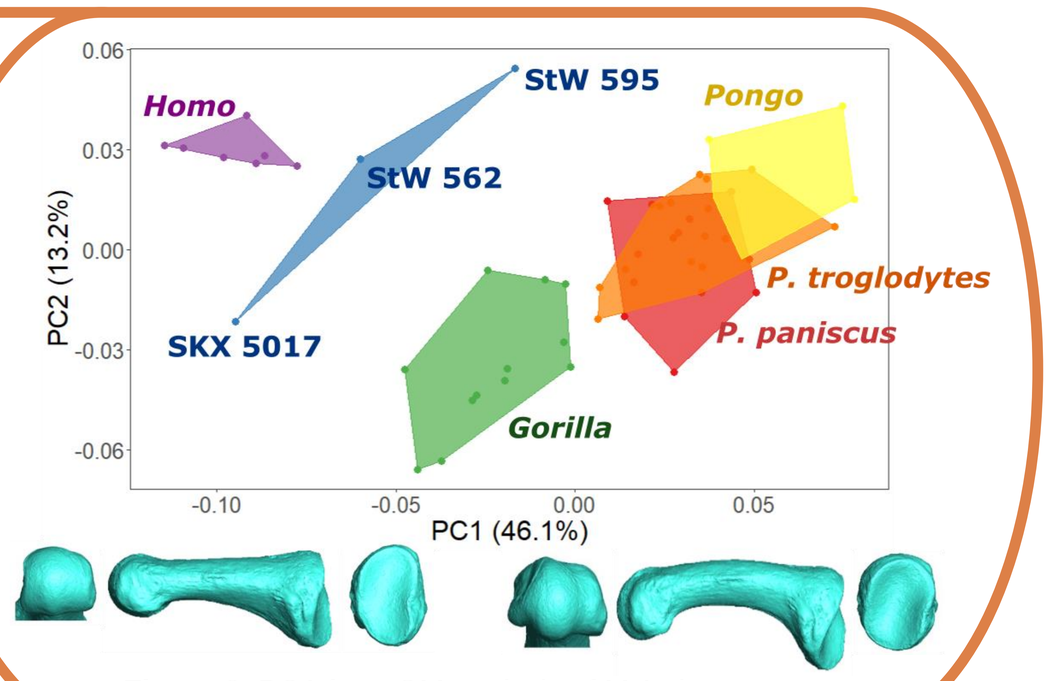


**Figure 3.** PCA from GM analysis of Mt1 shape

## Midshaft Cross Sectional Geometry

- CSG analysis at mid-shaft demonstrates that the StW 595 metatarsal is more gracile than StW 562 and SKX 5017, **with StW 595 being most similar to *Pongo*** in both J and relative CSA
- The StW 562 and SKX 5017 Mt1s are similar in both J and CSA/length, being most similar to *Pan* and *Homo.*

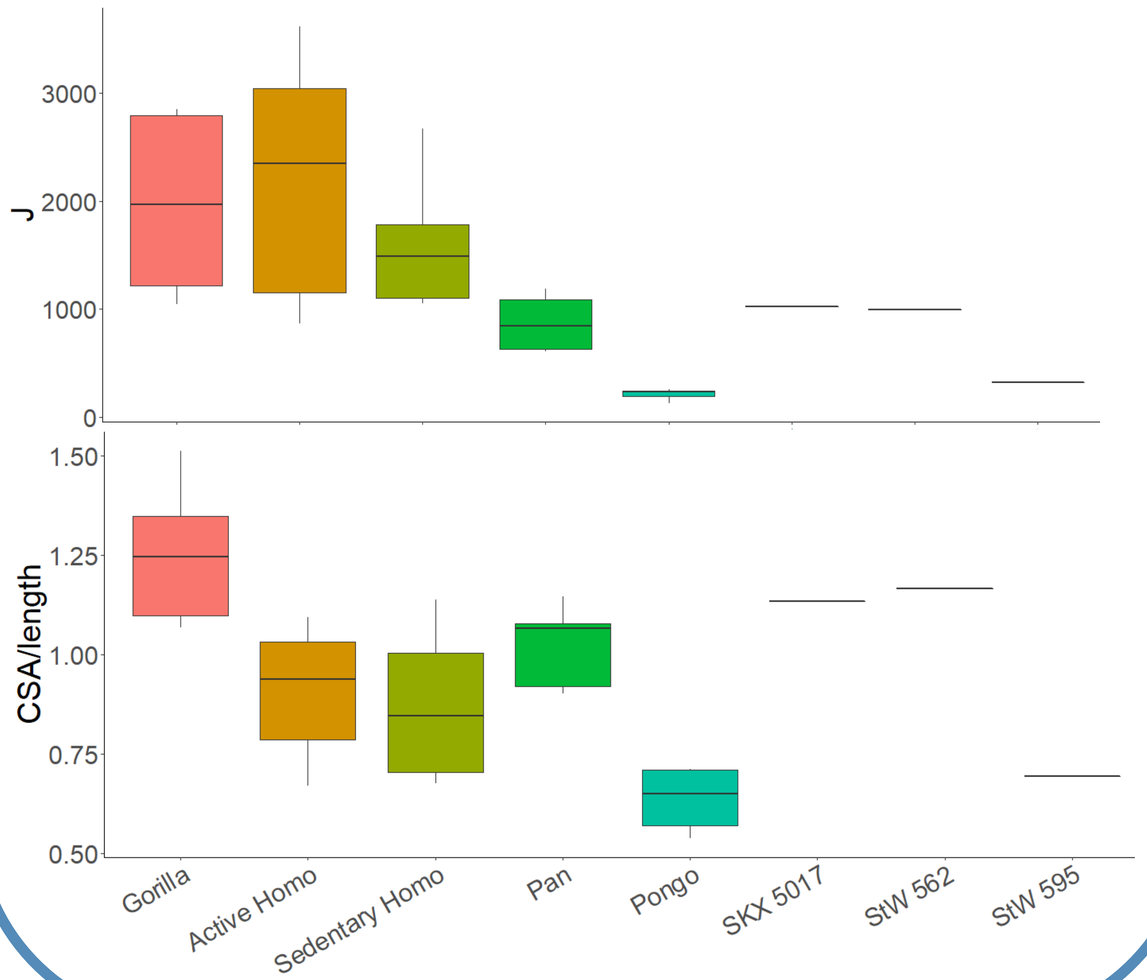


**Figure 4.** Results of CSG analysis at midshaft

## Internal Morphology – Whole-Bone Analysis

- The distribution of the internal trabecular bone and cortical thickness of the Mt1 reflects the degree of first **metatarsophalangeal dorsiflexion** in extant apes and humans and other aspects of function[6,7].
- **StW 595:** despite its lacking dorsal doming of the metatarsal head, there is a concentration of bone dorsally suggesting a high degree of dorsiflexion. **StW 562:** although the head of StW 562 is dorsally domed, the highest concentration of bone is not as dorsally placed as SKX 5017 or SK 1813 (*P. robustus*/*Homo* sp.).
- The StW 595 and StW 562 fossils differ in the distribution of cortical bone.

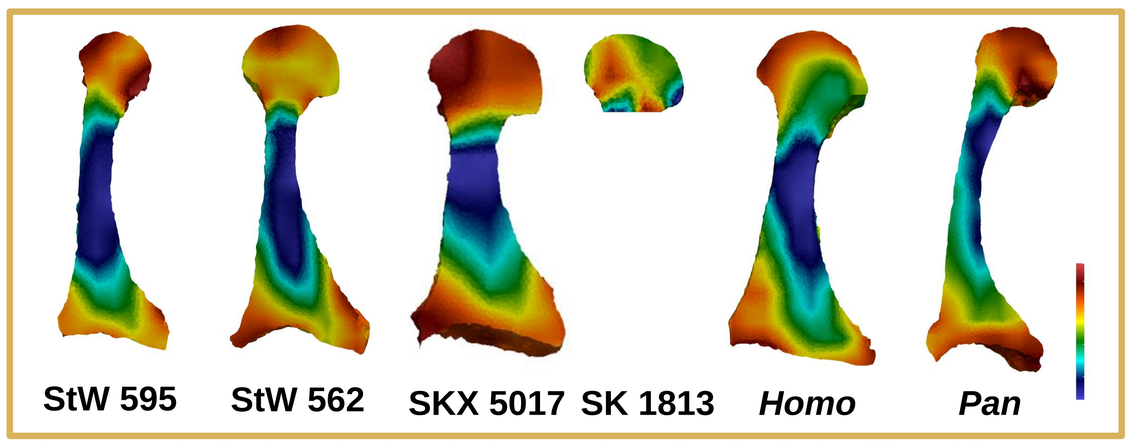


**Figure 5.** Distribution of trabecular bone volume fraction in fossil hominins, *Homo* and *Pan*, scaled to data range of each individual (some images from [5])

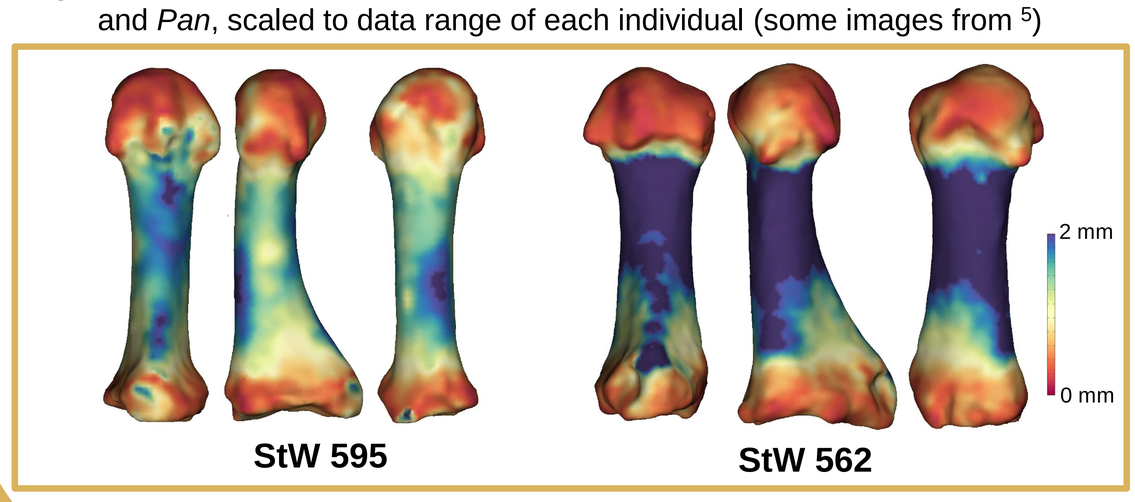


**Figure 6.** Distribution of cortical thickness in the StW 595 and StW 562 Mt1s, scaled from 0-2mm

## Conclusions

- StW 595 and StW 562 differ in aspects of their external shape and internal cortical and trabecular bone structure.
- Results suggest **functional and/or taxonomic diversity may be present in the postcranial specimens from Sterkfontein MB4**, supporting previous research[1-5].

**ACKNOWLEDGEMENTS:** This research received funding from the Max Planck Society and the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 819960). For access to specimens we thank Christophe Boesch and Roman Wittig (Max Planck Institute for Evolutionary Anthropology and Taï Chimpanzee Project), Birgit Großkopf (Georg-August Universität Göttingen), Chris Deter and Patrick Mahoney (University of Kent), Frieder Mayer and Christiane Funk (Museum für Naturkunde - Leibniz Institute for Evolution and Biodiversity Science), Anneke van Heteren (Zoologische Staatssammlung München), Inbal Livne (Powell-Cotton Museum), Miriam Tawane (Ditsong National Museum of Natural History) and the Evolutionary Studies Institute, University of Witwatersrand. For methodological development we thank Dieter Pahr.

**REFERENCES:**

1. Clarke. 2008. *South African Journal of Science* 104:443-449.
2. Grine. 2019. *Comptes Rendus Palevol* 18:335-352.
3. Fornai et al. 2021. *Communications Biology* 4:347.
4. Zipfel & Wunderlich. 2020. In *Hominin Postcranial Remains from Sterkfontein, South Africa, 1936-1995.* Oxford University Press
5. DeSilva et al. 2012. *Journal of Human Evolution* 63:487-496.
6. Komza & Skinner. 2018. *Journal of Human Evolution* 131:1-21.
7. Jashashvilli et al. 2015. *PLoS ONE* 10: e0117905.