What can fossil footprints teach us about our evolution?

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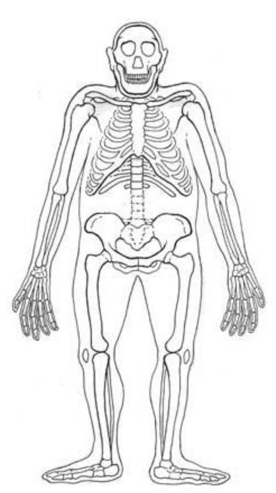
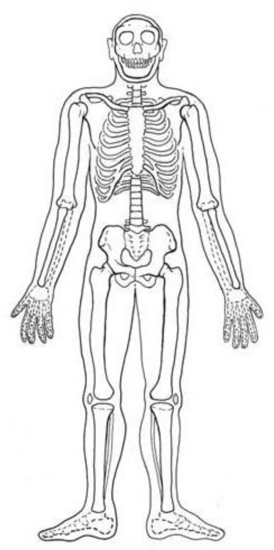
INTRODUCTION

1. The emergence of the genus *Homo* (~2 million years ago) marked a distinct change in overall body plan (and possibly locomotion) from our earlier relatives who belonged the genus *Australopithecus* (e.g., "Lucy").

2. Skeletal evidence that can be used to test hypotheses about this transition is limited, and fragmentary, leading to different conclusions regarding the interpretation of the same skeletal material.



Early *Homo* shows:
- Longer legs
- Shorter arms
- Narrow hips
- Narrow thorax
- Adaptations to long-distance walking or running?

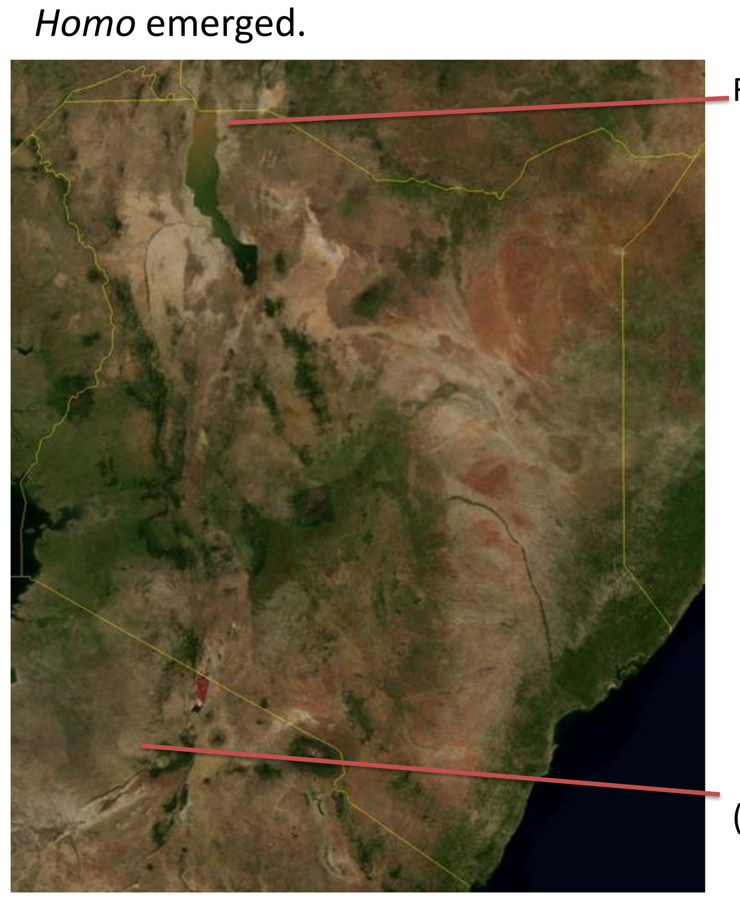


Australopithecus   *Homo*

(Bramble and Lieberman, 2004)

Australopithecus partial foot skeleton (Haile-Selassie et al., 2012)

3. Fossil footprints are a unique and important form of data because they circumvent issues of skeletal interpretation by preserving direct records of anatomy and gait. New discoveries of 1.5-million-year-old early human footprints at Ileret, Kenya offer novel comparisons to the famous 3.6-million-year-old footprints discovered in the late 1970s at Laetoli, Tanzania, which can help us understand changes in anatomy and locomotion over those two million years of human evolution, which overlap the era when the genus *Homo* emerged.



FwJj14E, Ileret, Kenya (~1.5 million years)

Laetoli, Tanzania (~3.6 million years)

4. **BUT, we know very little about how aspects of anatomy and gait are actually preserved in fossil footprints.**

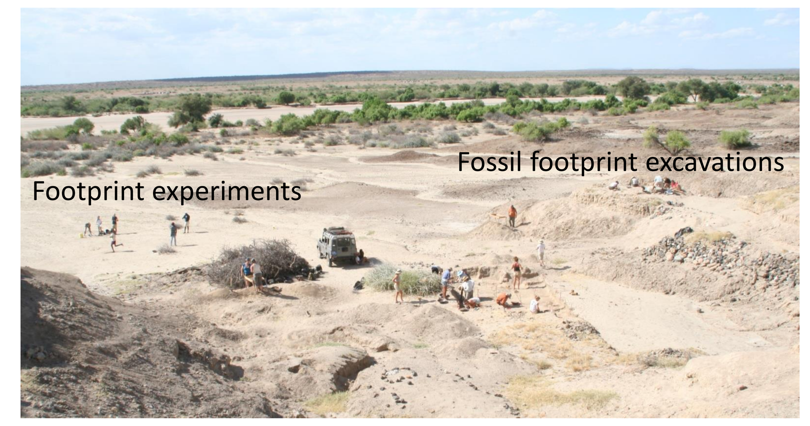
RESEARCH QUESTION

Can we use footprints to make predictions about the anatomy and gait of the person who created them?

- How tall were they?
-How much did they weigh?
- How fast were they moving?
- Did their feet function the same way as ours?

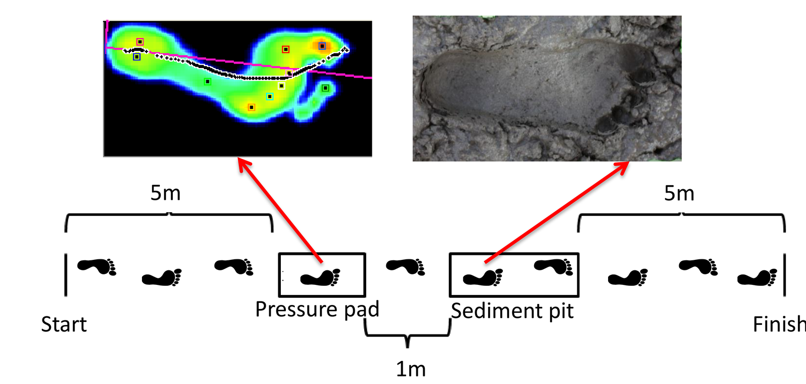
MATERIALS AND METHODS

TO INVESTIGATE OUR RESEARCH QUESTION, WE TOOK AN EXPERIMENTAL APPROACH WITH MODERN PEOPLE:

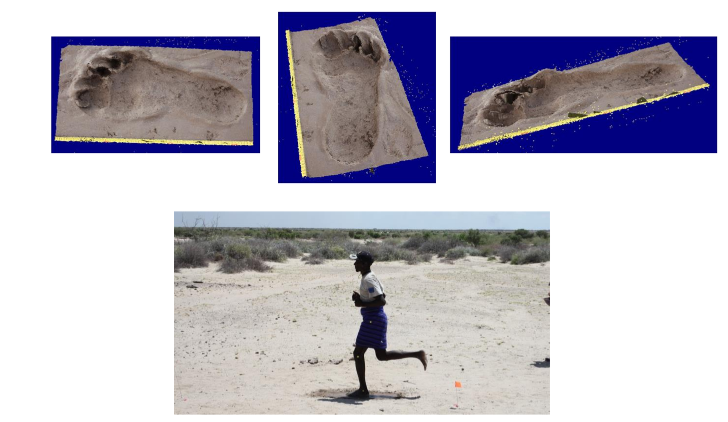


Because shoes influence the anatomical development of the foot, we conducted experiments on footprint formation with habitually unshod Daasanach people from Ileret, Kenya, next to the site of our fossil excavations.

In these experiments, we first took biometric measurements including height, weight, and foot dimensions.



Each subject walked and ran along a ~15m long trackway. In the center was a 1m plantar pressure pad and a 1.5m pit of reconstituted mud taken directly from a fossil footprint-containing sedimentary layer.



We used photogrammetry to create 3-dimensional models of each footprint. We also digitized video recordings of each trial to measure speed and other motion-related variables.

ANALYSIS AND RESULTS

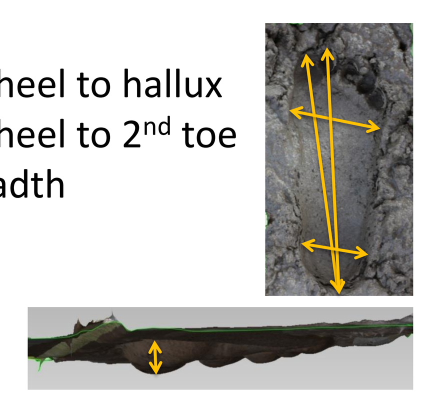
Using our experimentally-collected data, we tested how well footprint measurements (which could also be taken from the fossil prints) could predict height, weight, kinematic variables, and foot function of the individual who made them. All predictive models were generated using random forests (Breiman, 2001).

1) How well can linear dimensions of footprints predict overall body size?

<u>Predictors</u>

Length from heel to hallux
Length from heel to 2nd toe
Forefoot breadth
Heel breadth

Mean depth

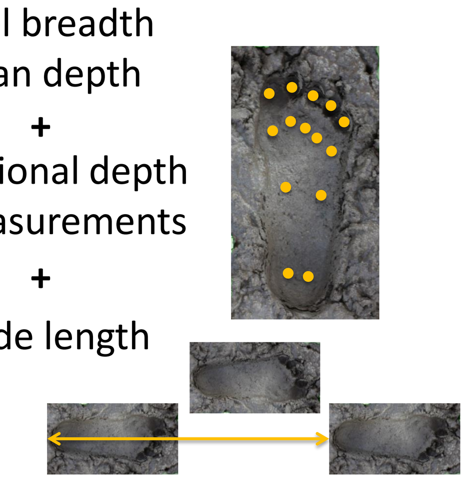


Variable predicted	Variance explained (%)	Prediction interval (95%)
Stature (cm)	68	+/- 9.6 cm
Body mass (kg)	63	+/- 6.6 kg

2) How well can linear dimensions, internal topography, and spatial relationships of footprints predict kinematic variables?

<u>Predictors</u>

Length from heel to hallux
Length from heel to 2nd toe
Forefoot breadth
Heel breadth
Mean depth
+
Regional depth measurements
+
Stride length



<u>Kinematic variables</u>

Froude number – a measure of speed relative to size
Duty factor – proportion of stride time that the foot and ground are in contact
Stride frequency – inverse of stride duration

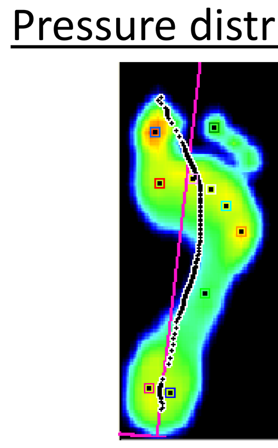
Variable predicted	Variance explained (%)	Prediction interval (95%)
Froude number	76	+/- 1.0
Duty factor	83	+/- 0.1
Stride frequency (sec^{-1})	60	+/- 0.3 sec^{-1}

3) How well can linear dimensions, internal topography, and spatial relationships of footprints predict foot function (pressure)?

<u>Predictors</u>

Length from heel to hallux
Length from heel to 2nd toe
Forefoot breadth
Heel breadth
Mean depth
Regional depth measurements
Stride length

<u>Pressure distribution</u>



Variable predicted	Variance explained (%)	Prediction interval (95%)
Hallux max pressure	4.1	+/- 0.54
Lateral toes max pressure	6.1	+/- 0.22
First metatarsal max pressure	14.0	+/- 0.52
Second metatarsal max pressure	14.4	+/- 0.42
Third metatarsal max pressure	5.6	+/- 0.50
Fourth metatarsal max pressure	4.2	+/- 0.57
Fifth metatarsal max pressure	7.1	+/- 0.49
Lateral midfoot max pressure	14.3	+/- 0.24
Lateral heel max pressure	9.9	+/- 0.49
Medial heel max pressure	14.5	+/- 0.52

CONCLUSIONS

1) **The sizes of footprints can produce robust estimates of the overall body sizes of the individuals who produced them.**
2) **Footprint measurements can also provide robust predictions of gait kinematics.**
3) **Measurements of footprints cannot, at this point, produce reliable predictions about the details of an individual's foot function. A more complex modeling approach will be needed.**

Together, these results suggest that fossil hominin footprints, such as those at Ileret , Kenya and Laetoli, Tanzania, can provide robust estimates of body size and gait kinematics of the printmakers. But, more work will be needed to produce detailed comparative analyses of their foot function.

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