# Footprint Lab

The discovery and description of Pliocene footprints at Laetoli, Tanzania, was a signal event in the study of human evolutionary anatomy. It is evident from these footprints that Pliocene hominins at Laetoli achieved a fully upright, freestanding bipedal gait by 3.6 Ma.

At site G, see Figure 1, there are two parallel trails left by three individuals; a solo set of prints (G1) alongside another set of prints (G3) that is superposited on the third (G2). The trails extend northwards ca. 25 cm apart, too close for the hominids to have walked abreast.

Direct measurement of the footprints yields essential gait information, such as the stride length and angle of step. Here, we will explore if it is possible to extrapolate kinematic and social behavior from this fossil record.

Your objective is to complete the 5 steps below (+deliverables and submit instructions) in order to:

* Calculate the relationships between step length, cadence, and speed of walking in a population of undergraduate students
* Compare them to that of G1 to see if they are significantly different
* Explore the relationship between kinematics, fossil evidence, and behavior

## Data Acquisition

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Step 1: Measure your height, or stature *(S)* and measure your foot length (*l*), i.e. the linear distance from the posterior edge of your heel bone (calcaneus) to the end of your longest toe bone (phalanx).

Write your stature *(S)* here: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(m)

Write your foot length *(l)* here: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(m)

You will now walk in some damp sand to create a set of your own footprints. Make sure to walk normally!

Step 2: Measure your stride length (*L*), defined as the distance between two consecutive heel strikes with the same foot, which means that a stride is made up of two footprints on the same side.

Write your stride length (*L*) here: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(m)

Step 3: Measure the degree of lateral rotation in your right foot, or out-toeing angle.

Write it here: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(degrees)

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### Data Analysis

Step 4: Now we will compile the data from all the students. Input your written data from this sheet into the google form. Be careful when entering your data! Errors in data input can skew our analysis.

Step 5: Copy the read only data google sheets data into your own copy that you can manipulate. Click on ‘File’ → ‘Make a copy’ → and save to your own Google drive. In your Google sheet, under column G, type a new column header called “Relative Stride Length (L’)”. In this column, calculate the relative stride length (*L’*) of all individuals in your data set.

Relative stride length,

Under column H, type a new column header called “Relative Speed (V’)” and calculate the relative speed (*V’*) of all individuals in your dataset. The curvilinear equation for predicting *V’* from *L’* is

where constants = 66, and = 0.58

Under column I, type a new column header called “Foot Length per Stride (l’)” and calculate the foot length per stride (*l’*) of all individuals in your data set.

Foot length per stride,



Deliverable 1: The middle graph on the right in the google sheet will be automatically populated with the data that you have copied and provided. It is titled “Relative Stride Length vs Relative Speed” and is a bivariate plot with relative speed (*V’*) on the X-axis and relative stride length (*L’*) on the Y-axis. The red line is a trend line. This plot represents the relationship between stride-length (in units based on fractions of stature) and speed (in units based on fraction of stature covered overground per second) for our class sample.

Use the trend line to estimate what you would expect the relative speed (*V’*) of the hominins to be based on their stride length if they were part of the class population. Trail 1 (*L’* = 0.65) and Trail 2 (*L’* = 0.72). Compare this to their actual relative speed (represented as red dots).

Deliverable 2: The bottom graph on the right is a bivariate plot with relative speed (*V’*) on the X-axis and foot length per stride (*l’*) on the Y-axis, and a red trend line. This plot represents the linear relationship between foot length and speed, confirming that it is possible to estimate walking speed without measuring stature.

Use the trend line to estimate what you would expect the relative speed (*V’*) of the hominins to be based on their foot length if they were part of the class population. Trail 1 (*l’* = 4.18) and Trail 2 (*l’* = 4.39). Compare this to their actual relative speed (represented as red dots).

Deliverable 3: Calculate *μ -* the mean lateral rotation of the right foot of the class. You can do this in sheets by using the AVERAGE function with the lateral rotation column. Also calculate the standard deviation of the class data. The equation for standard deviation is: . But you can just use the STDEV function on google sheets.

Deliverable 4: Now we will see whether the tibial torsion of G1 is unusual compared our class population. To do this we will calculate what is called a Z score for the G1 lateral rotation. A Z score is a measure of how many standard deviations an observation is from a sample. The larger the Z score, the more unusual an observation is. In a normal distribution, a Z score with a magnitude greater than 3 is highly unlikely.

In your copied Google sheet, the top graph on the right is a histogram plot of the lateral rotations. Calculate the Z score for the G1’s right foot data point (represented as the right dot on the far right of the plot).

where X = the lateral rotation of G1

Based on this Z score, would you consider the lateral rotation of G1 abnormal?

### Making Inferences About Walking Speed

Deliverable 5: Were these hominins walking quickly or slowly relative to what we would expect to see if they were part of our class population? Answer in 3-5 sentences, based on the data as well as your own intuition.

Making Inferences About Social Behavior

Deliverable 6: Which of the scenarios below is most compelling to you? Do you have your own interpretation of the reasoning behind G1’s exceptionally large lateral rotation? As well as any speculation of the hominins’ social behavior?

Feel free to expand or edit one of the above inferences/speculations or create a new one. Answer in 3-5 sentences.

| Interpretation One  Near the area where the ball of the femur goes into the hip are trochanters – protuberances where the muscles attach – as well as a thin gap of bone between, called the femoral neck. This neck can break quite easily when significant force impacts the footplate of the foot and those forces get transmitted up through the leg (e.g., during head-on car collisions).  When a proximal break in the femur occurs, traction needs to be applied. Naturally, the big thigh muscles on the side of the body are pulling the bone and twisting the femur. Thus, to heal in the correct configuration femoral traction must be applied to the bone to help prevent that twisting. These early hominins would not have had access to the type of traction needed to achieve this.  One interpretation of the footprints is that G1 might have fallen out of a tree and suffered a break at the proximal femur. When it was healed, it caused the foot to prominently rotate out.  If they suffered an accident that caused enough force to break the bone in this way, G1 would not be able to walk for weeks or months. During this period other community members of that social group would have to care for them and provide food. Instead of ejecting G1 out of the community, the members took care of G1 as they healed.  Interpretation Two  The second interpretation is that G1 was a female with an infant. The infant could not travel across the mud on its own, thus G1 would carry the infant on her hip. This would explain the adjustment in gait and the asymmetry in the footprints.  This would imply that Females in the community are in charge of taking care and monitoring the children. Females keep their infants close to them, even during other Steps or travels. |
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Deliverable 7: Are you comfortable speculating social behaviors based on observations of fossil records? What are the bounds of inferences/speculations when it comes to fossil examination? Answer in 3-5 sentences.