Tracks of a Killer: Using footprints to estimate height

Analyze the relationships between shoe size, stride length, and height, and then use that information to identify the likely killer.

The body of famous pop music producer Jonathan Wallace was found in his bathtub. It is our hypothesis that an intruder surprised the victim and drowned him. The only clue at the crime scene was a set of muddy footprints leading from a nearby window to the bathroom and back again. The footprints were smeared, so their exact size could not be determined. The soles of the shoes had no pattern. It will be difficult to match the footprints to any particular pair of shoes.

Three suspects were questioned immediately following the murder:

Penelope Paige, pop star: 1.63 m /green eyes/blond hair
Possible motive: She is suing Wallace over the failure of her last album.

Rex Chapman, rock guitarist: 1.73 m /brown eyes/brown hair
Possible motive: He accused Wallace of stealing profits from his hit single “Walk It Off.”

Dirty Dawg, rapper: 1.83 m /brown eyes/black hair
Possible motive: He wants out of a record contract with Wallace.

Victim Jonathan Wallace. Found 2 p.m. on 10/5/05. Time of death estimated at between 8 and 10 a.m.

Footprints presumed to have been left by the murderer. Prints are 0.25-0.3 m long. Heel-to-heel stride length is 0.64-0.65 m.
Tracks of a Killer

OBJECTIVES

• Determine if there is a relationship between the length of a person’s stride and his or her height.
• Determine if there is a relationship between the size of a person’s shoes and his or her height.
• Efficiently gather data to test for correlations between height, shoe size, and stride length.
• Use a linear regression model of the data to predict height based on stride length.

MATERIALS

- computer
- Logger Pro
- 3 metric tape measures or meter sticks
- chalk or tape

PROCEDURE

Part I: Collecting Data

1. Set up three stations with two people at each, one person to collect data and one person to record data.
   • At station 1, use the tape measure or meter stick to measure each person’s height without shoes to the nearest 0.01 m, and record it in the Evidence Record next to the person's name.
   • At station 2, have each person remove his or her right shoe. Turn the shoe over and use a ruler to measure the distance from the tip of the toe to the end of the heel. Record the length of the person's shoe in the Evidence Record.
   • At station 3, mark a starting line with chalk or tape. Have each person stand with the backs of his or her heels at the edge of the starting line. Starting at this point, each person should take 10 normal-length walking steps in a straight line (see the diagram below). After the 10th step, the person should stop and bring his or her heels together. Mark the final position of the back of the person’s heels, and measure the distance to the nearest 0.01 m between that mark and the edge of the starting line. Calculate the average stride length by dividing this distance by 10. Record each person’s average stride length to the nearest 0.01 m in the Evidence Record.

![Diagram showing stride measurement](image)

2. When all of the data are collected, compile a complete record for all individuals on a master Evidence Record.
Part II: Entering the Data

3. Begin by opening the file “01 Tracks of a Killer” from the *Forensics with Vernier* folder of Logger Pro.

4. Enter the data recorded in the Evidence record in Logger Pro.
   a. Click on the first cell in the Height column in the table. Type in the height of the first student recorded in the Evidence record, and press the ENTER key.
   b. Move the cursor to the first cell in the Shoe Length column. Type in the length of the first student’s shoe, and press the ENTER key.
   c. Move the cursor to the first cell in the Stride Length column. Type in the length of the first student’s average stride, and press the ENTER key.
   d. Continue in this manner to enter data for all the remaining students recorded in the Evidence record.

Part III: Analyzing the Data

Next, you will determine the equation for the straight line that fits your data the best. It is important to have an equation that describes the relationship between height and stride length. If you have an equation, you can predict the height of any person based on the length of the person's stride.

There is a specific kind of mathematical formula that can be used to determine the equation for a straight line that best fits a group of data points. It is called a linear regression. In order to use this formula, we have to assume that the relationship between height and stride length is linear. In other words, we have to assume that height and stride length are related by an equation that is in the following form:

\[ \text{Stride length} = (m)(\text{height}) + b \]

where the \( m \) and \( b \) are constants. It is possible to calculate the equation by hand, but it can take a long time. However, with the Logger Pro linear regression analysis tool, you can quickly calculate the \( m \) and \( b \) for your data.

5. Perform a linear regression of the average stride length vs. student height data.
   a. Click on the graph of average stride length vs. student height to select it.
   b. Click the Linear Fit button. A best-fit linear regression line will be shown for the data points. This calculates the equation for the straight line that best fits your data. The screen will display the \( m \) (slope) and \( b \) (intercept) values that make the linear equation fit the data. The correlation value tells you how well the line fits the data. The closer the value is to 1 the better the line fits the data.
   c. Write the linear regression equation for your data in your Evidence Record. Also record the displayed calculated correlation value.

6. Repeat Step 5 to determine whether or not there is a relationship between student height and shoe length.

7. Answer the questions in the Case Analysis, using your results.
### EVIDENCE RECORD

<table>
<thead>
<tr>
<th>Student Name</th>
<th>Height (m)</th>
<th>Shoe Length (m)</th>
<th>Stride Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Equation describing the relationship between stride length and height: __________

Correlation value for stride length vs. height length: __________

Equation describing the relationship between shoe size and height: __________

Correlation value for shoe size vs. height: __________
CASE ANALYSIS

1. Based on your data, should a linear model be used to represent your data? Explain your answer?

2. What is the correlation value for the straight line that best describes your data for student stride length vs. height? Do you think the straight line fits these data well?

3. Based on your data, is there a linear relationship between student height and shoe length?

4. Do you think that it is possible to infer a person’s height from his or her shoe size? Explain your answer.

5. Using the relationship between height and stride length that you calculated, determine the approximate heights of people with the following stride lengths:
   a. 0.75 m
   b. 0.45 m
   c. 0.50 m

6. Using the relationship between height and stride length that you calculated, predict the stride length of a person who is not a student in your class (for example, your teacher, your principal, or a student in a different class) based on his or her height. Then measure the person’s actual stride length. How close was your prediction to the actual stride length?

7. Suppose you measure the stride length of a set of footprints, you predict that the person who made the footprints is 1.75 m tall, and you later find out that the person who made the footprints is actually only 1.52 m tall. Give possible reasons that your prediction was incorrect.

8. Using the relationships that you calculated, determine which of the three suspects most likely left the footprints to and from Jonathan Wallace’s bathroom. Show all your calculations.
   (Hint: In the equation that you wrote down, \( x \) is stride length and \( y \) is height.)
Vernier Lab Safety Instructions Disclaimer

THIS IS AN EVALUATION COPY OF THE VERNIER STUDENT LAB.

This copy does not include:

- Safety information
- Essential instructor background information
- Directions for preparing solutions
- Important tips for successfully doing these labs

The complete Forensics with Vernier lab manual includes 14 labs and essential teacher information. The full lab book is available for purchase at:
http://www.vernier.com/cmat/fwv.html