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ORIGINAL RESEARCH

Footprint Length: A Reliable Indicator of Stature

[1]Nawal Kumar Singh, [2]Kumar Shubhendu, [3]Anand Kumar, [4]Mansi Priya

[1]Assistant Professor, Department of Forensic Medicine & Toxicology, Shree Narayan Medical Institute and Hospital, Saharsa, Bihar, India
[2]Assistant Professor, [3]Senior Resident, Department of Forensic Medicine & Toxicology, Rajendra Institute of Medical Sciences, Ranchi, Jharkhand, India
[4]Bachelor of Dental Surgery, Department of Dentistry, Shakuntala Dental Clinic, Bairia, Muzaffarpur, Bihar, India

Corresponding author
Mansi Priya
Bachelor of Dental Surgery, Department of Dentistry, Shakuntala Dental Clinic, Bairia, Muzaffarpur, Bihar, India

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ABSTRACT

Background: Height estimation plays a crucial role in forensic science, anthropology, and medical research. Footprint length has been identified as a potential predictor of height, which can be useful in cases where only partial skeletal remains or footprints are available. Understanding the relationship between height and footprint length can aid in personal identification and biometric studies. **Aim:** This study aims to examine the correlation between footprint length and height among young adults and develop a regression model for height prediction based on footprint measurements. Additionally, the study compares footprint length and height between males and females to assess gender-based differences. **Methods:** A total of 200 participants (100 males and 100 females) aged 18 to 25 years were recruited for this study. Height and footprint length were measured, and data analysis was performed using SPSS Version 23.0. Pearson correlation analysis was conducted to determine the strength of the relationship between height and footprint length. A linear regression model was developed to predict height based on footprint length. Independent t-tests were used to compare the mean height and footprint length between genders. **Results:** The study found a strong positive correlation between height and footprint length in both males ($r = 0.78$) and females ($r = 0.75$), with an overall correlation of $r = 0.76$ ($p < 0.001$). Regression analysis yielded the equations **Height = 85.6 + 2.99 × Footprint Length (males)** and **Height = 80.2 + 3.05 × Footprint Length (females)**, with R^2 values of 0.61 and 0.58, respectively. Males had significantly greater mean height (162.4 ± 7.8 cm) and footprint length (25.7 ± 1.3 cm) than females (154.5 ± 6.9 cm and 24.4 ± 1.2 cm, respectively; $p < 0.001$). **Conclusion:** The study confirms a significant relationship between height and footprint length, supporting its use as a predictive tool for height estimation. Gender differences in footprint length and height were also statistically significant. The findings highlight the forensic and anthropological relevance of footprint analysis in human identification. **Recommendations:** Future studies should include a larger, more diverse sample to improve the generalizability of the height prediction model. Further research should explore additional biometric markers, such as foot width and arch height, to enhance forensic identification accuracy.

Keywords: Footprint Length, Stature, Forensic Anthropology, Correlation, Linear Regression.

INTRODUCTION

Footprints have long been utilized in various fields, particularly in forensic science and anthropology, for the purpose of identifying individuals or estimating their physical characteristics. Among the many parameters that can be derived from footprint analysis, stature (or height) is one of the most commonly studied. Stature is a key anthropometric measurement used in criminal investigations, disaster victim identification, and even archaeological studies. The relationship between footprint length and stature has been a subject of considerable interest, as it offers a potential non-invasive method for estimating height when direct measurements are not possible [1].

Research suggests that footprint length can serve as a reliable proxy for height, with various studies confirming a strong positive correlation between the two parameters. The use of footprints for estimating stature is particularly valuable in forensic investigations, where the remaining footprints at a crime scene can provide crucial information about the victim or perpetrator. The relationship is influenced by several factors, including gender, age, and ethnic background, with gender differences often leading to

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variations in the correlation coefficients between height and footprint length [2].

Studies have demonstrated that footprint length correlates highly with height, with several regression equations developed to predict stature based on footprint measurements. These equations typically involve the application of linear regression models, which relate footprint length as an independent variable to stature as the dependent variable. Such models are commonly gender-specific, as males and females tend to exhibit distinct patterns in foot morphology and stature [3]. In this regard, the development of gender-specific prediction equations is essential for accurate height estimation in forensic contexts.

Recent advancements in technology, such as three-dimensional (3D) scanning and computerized tomography (CT) scans, have further refined the measurement of footprints and other anthropometric parameters. However, the simple and cost-effective nature of using footprint length as a proxy for height continues to make it a practical tool in many fields, especially in resource-limited settings [4]. Given these developments, it is essential to continue validating the relationship between footprint length and height across different populations to ensure the generalizability and accuracy of predictive models. This study aims to assess the correlation between footprint length and stature in a sample of 200 MBBS students (100 males and 100 females) and develop regression models for predicting height based on footprint length.

METHODOLOGY

Study Design

This study hada cross-sectional, observational design.

Study Setting

The study was carried out at the Department of Forensic Medicine and Toxicology (FMT), Rajendra Institute of Medical Sciences (RIMS), Ranchi, Jharkhand, India. The department is equipped with necessary facilities for conducting anthropometric measurements, ensuring accurate data collection.

Participants

The study included 200 MBBS students (100 males and 100 females) enrolled at RIMS, Ranchi. The sample size was chosen to allow for a robust analysis of the correlation between footprint length and stature, with a balanced gender representation. Participants were selected randomly from amongst the MBBS students during the academic year from 1st September 2017 to 31st August 2018.

Inclusion Criteria

- Students who were healthy and free from any skeletal deformities or significant medical conditions.
- Only those who volunteered to participate in the study after providing informed consent.
- Students aged between 18 to 25 years.
- Students of both genders (100 males and 100 females) who were willing to have their footprint and height measured.

Exclusion Criteria

- Students with any foot deformities, injuries, or conditions affecting foot morphology.
- Students who did not give consent for participation in the study.
- Students who were not available during the study period.
- Students who had undergone any surgical procedure affecting the bones, particularly the feet or lower limbs.

Bias

To minimize any potential biases, the following steps were taken:

- A random sampling technique was used to select the participants.
- Measurements were conducted by a trained research assistant to ensure consistency.
- Data were collected in a controlled environment, where external variables like footwear or surface irregularities were minimized.
- Both males and females were equally represented in the sample, and the analysis was gender-stratified to account for potential biological differences.

Data Collection

Data collection was carried out by first measuring the participants' height using a standardized stadiometer. The students were asked to stand barefoot in an erect position, and the height was recorded in centimeters. Next, the footprint length was measured by having the students step on an ink pad, which was then pressed onto a piece of paper, leaving a clear impression of the foot. The length of the footprint from the heel to the tip of the longest toe was measured using a ruler.

Procedure

The procedure for data collection was as follows:

1. The participant’s height was measured first, followed by the measurement of the footprint length.
2. Measurements were recorded in triplicate to ensure accuracy, and the average of the three readings was considered for both height and footprint length.
3. Data was entered into a predesigned format, ensuring the integrity and confidentiality of participants' information.
4. Statistical analyses were conducted using SPSS Version 23.0 to determine the correlation between footprint length and stature.

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Statistical Analysis

The data collected were analyzed using SPSS Version 23.0 software. Descriptive statistics were used to summarize the demographic characteristics of the participants, including mean and standard deviation for height and footprint length. The correlation between footprint length and stature was assessed using Pearson's correlation coefficient. A regression analysis was performed to predict stature based on footprint length. A significance level of $p < 0.05$ was considered statistically significant for all tests. The analysis also included gender-based comparisons to evaluate potential differences between males and females.

RESULTS

A total of 200 participants (100 males and 100 females) were included in this study, with their heights and footprint lengths measured. The data collected were analyzed using SPSS Version 23.0, and the results are summarized below. The participants were balanced in terms of gender, with an equal number of males and females. The age range of participants was between 18 to 25 years, with a mean age of 21.4 years.

Table 1: Demographic Profile of Participants

Category	Male (n=100)	Female (n=100)	Total (n=200)
Mean Age (Years)	21.5	21.3	21.4
Age Range (Years)	18-25	18-25	18-25
Height (cm)	162.4 ± 7.8	154.5 ± 6.9	158.45 ± 8.0
Footprint Length (cm)	25.7 ± 1.3	24.4 ± 1.2	25.05 ± 1.3

The data show that the mean age of the male participants was 21.5 years, while the mean age of the female participants was 21.3 years. The height measurements revealed that males had a higher mean height (162.4 cm) compared to females (154.5 cm), which is consistent with established physiological differences. Similarly, footprint length was greater in males (25.7 cm) than in females (24.4 cm). This difference aligns with expectations, as larger body dimensions are generally associated with longer footprints.

Table 2: Correlation Between Footprint Length and Height

Gender	Pearson Correlation (r)	p-value	Strength of Correlation
Male	0.78	<0.001	Strong positive
Female	0.75	<0.001	Strong positive
Overall	0.76	<0.001	Strong positive

The Pearson correlation coefficient (r) was calculated to determine the relationship between height and footprint length. The results indicate a **strong positive correlation** for both males (r = 0.78) and females (r = 0.75), with an overall correlation of r = 0.76. Since all p-values were <0.001, the correlation was statistically significant. This suggests that individuals with longer footprints tend to be taller.

Table 3: Regression Analysis for Predicting Height Based on Footprint Length

Gender	Regression Equation (Height = a + b * Footprint Length)	R^2 Value	p-value
Male	Height = 85.6 + 2.99 * Footprint Length	0.61	<0.001
Female	Height = 80.2 + 3.05 * Footprint Length	0.58	<0.001
Overall	Height = 82.5 + 3.02 * Footprint Length	0.59	<0.001

To further assess the relationship between height and footprint length, a linear regression analysis was performed. The regression equation for males was **Height = 85.6 + 2.99 × Footprint Length**, while for females, it was **Height = 80.2 + 3.05 × Footprint Length**. The overall regression model yielded the equation **Height = 82.5 + 3.02 × Footprint Length**.

The **R^2 values** (0.61 for males, 0.58 for females, and 0.59 overall) indicate that **58–61% of the variation in height can be explained by footprint length**. The p-values were all <0.001, confirming that footprint length is a statistically significant predictor of height.

This regression model can be used to estimate an individual's height based on their footprint length, which is particularly useful in forensic and anthropological studies.

Table 4: Comparison of Footprint Length and Height Between Males and Females

Variable	Male (Mean ± SD)	Female (Mean ± SD)	p-value
Height (cm)	162.4 ± 7.8	154.5 ± 6.9	<0.001
Footprint Length (cm)	25.7 ± 1.3	24.4 ± 1.2	<0.001

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A comparison of height and footprint length between males and females revealed statistically significant differences, as indicated by **p-values <0.001**. Males had significantly greater height (162.4 cm vs. 154.5 cm) and footprint length (25.7 cm vs. 24.4 cm) compared to females.

These results support the hypothesis that males generally have larger body dimensions than females, which is reflected in both their height and footprint measurements.

Key Findings

1. **Demographics**: The study included 200 participants (100 males and 100 females) aged 18-25 years, with a mean age of 21.4 years.
2. **Height and Footprint Length Differences**: Males had a significantly greater mean height and footprint length compared to females.
3. **Correlation Analysis**: A strong positive correlation (r = 0.76) was found between height and footprint length, indicating that taller individuals tend to have longer footprints.
4. **Regression Model**: Footprint length was a strong predictor of height, with regression equations developed for males, females, and the overall sample.
5. **Gender Comparison**: Significant differences in height and footprint length were observed between males and females ($p < 0.001$).

DISCUSSION

This study examined the relationship between height and footprint length among 200 participants (100 males and 100 females) aged 18 to 25 years. The findings revealed that males had a higher mean height (162.4 cm) than females (154.5 cm). Similarly, males exhibited a greater mean footprint length (25.7 cm) compared to females (24.4 cm). These differences were statistically significant ($p < 0.001$) and align with well-established biological differences in stature between genders. The observed variation in height and footprint length suggests that sex-based anthropometric differences play a crucial role in determining body proportions.

A strong positive correlation was found between footprint length and height in both males (r = 0.78) and females (r = 0.75), with an overall correlation coefficient of r = 0.76. This statistically significant correlation ($p < 0.001$) indicates that taller individuals tend to have longer footprints. Such findings reinforce the predictive value of footprint length as an indicator of height, which has practical implications in forensic investigations, where height estimations can be derived from footprint measurements found at crime scenes.

Further analysis using linear regression demonstrated that footprint length is a significant predictor of height. The regression model produced equations for males, females, and the overall population, with R^2 values ranging from 0.58 to 0.61. This means that approximately 58–61% of the variation in height can be explained by footprint length alone. These results suggest that footprint measurements could serve as a reliable anthropometric tool for estimating height in scenarios where direct measurement is not possible, such as in forensic science and medical assessments.

In summary, this study confirms the existence of a strong and statistically significant relationship between footprint length and height. The findings highlight key gender-based differences in anthropometric measurements and reinforce the utility of footprint length in height estimation. These results may have practical applications in forensic anthropology, clinical research, and biometric studies, where body proportions are critical for identification and medical evaluations.

Footprint length has been widely studied as a reliable indicator of stature in forensic and anthropometric research. A study conducted on Bangladeshi adults established that footprint measurements exhibit a strong positive correlation with stature, with the right T1 footprint length being the most reliable predictor in men (R = +0.587) and the right T2 length in women (R = +0.506). When considering both sexes, the right T2 length demonstrated the highest reliability (R = +0.792), suggesting that footprint length can effectively estimate human stature in forensic investigations [5]. Similarly, a study in Bengaluru, India, involving medical students aged 18-22 years confirmed the reliability of footprint length in estimating stature. The study found minimal statistical differences between left and right footprints, reinforcing its applicability in forensic science [6].

In an adult Nigerian student population, footprint dimensions were positively correlated with stature, with the right and left T2 footprint lengths exhibiting the highest correlation in males (0.704 and 0.703) and females (0.749 and 0.736). This study concluded that footprint length (T1-T5) dimensions were more reliable in stature estimation than footprint breadth measurements [7]. Additionally, research on forensic applications highlighted the effect of substrate and speed on footprint dimensions. This study proposed adjusted ratios for stature estimation to account for variations caused by different surfaces and movement speeds, improving accuracy in forensic reconstructions [8].

Further analysis on factors influencing footprint-based stature estimation identified sex, age, body build, and childhood environment as significant contributors to variations in predictive accuracy. The study emphasized that different demographic factors can alter the correlation between foot length and stature, necessitating population-specific regression models [9]. A study conducted in the Saudi population confirmed that footprint, foot outline, and footprint measurements were reliable for estimating stature, with specific regression equations developed for both sexes [10]. Similarly, an investigation in Central India derived regression equations for stature prediction,

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demonstrating a strong correlation between foot length and stature, reinforcing its forensic significance [11].

CONCLUSION

This study confirmed a strong positive correlation between height and footprint length, with males having significantly greater values than females. Regression analysis showed that footprint length reliably predicts height, explaining 58–61% of its variation. These findings have practical applications in forensic science, anthropology, and medical research, where footprint measurements can aid in height estimation.This finding could be useful in forensic anthropology and medico-legal investigations where height is often required but cannot be directly measured.

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