

## Compared Growth Patterns of the Foot and its Correlation with Stature in Western Uttar Pradesh and NCR Delhi Children Aged Between 6 and 10 Years

### Abstract

**Introduction:** The present study is based on the measurement of foot length and width which is correlated with the stature of 250 Western Uttar Pradesh and NCR Delhi children between 6 and 10 years of age. The measurements of the feet were taken on a flatbed scanner, and the image was captured and analyzed on a computer using Photoshop software. **Material and Methods:** The present study was conducted on 250 Western UP and NCR Delhi children who belong to different parts of Western UP and NCR Delhi. The stature of the person was measured from vertex to the floor while the individual was standing in an anatomical position. Obtained data were analyzed, and an attempt was made to find the correlation and to derive the linear regression formulae between stature and foot measurement. A good correlation was observed between stature and foot measurements. **Results:** Foot length of both right and left feet had a stronger correlation to stature with a value of 0.736, and the significance level was 0.01. Foot width of the right foot had a good correlation to stature with a value of 0.591, and the significance level was 0.01. Foot width of the left feet also had a good correlation to stature with a value of 0.588, and the significance level was 0.01. **Discussion and Conclusion:** Stature is an important parameter in determining the partial identity of unidentified bodies and dismembered remains. Determination and monitoring of growth rate may be possible with the correlation of foot length and stature. Results obtained would be useful for anthropologists and forensic medicine experts.

**Keywords:** Correlation, foot morphometry, stature, Western Uttar Pradesh and NCR Delhi children

### Introduction

Anthropometric measurements have been of help in racial determination, ergonomic in designing instruments and apparels. These parameters have been correlated with each other for forensic purposes like determination of the size of an individual from human remains. There is a dearth of literature on these parameters in different age groups of Western Uttar Pradesh and NCR Delhi. Defective footwear leads to foot disorders. This is a result of lack of proper measurements of the feet for designing footwear.

Major issues such as structural fatigue, slipper bumps, hammer toes, bunions, blisters, abrasions, ingrown nails, calluses, fungus, hallux valgus, Achilles tendon inflammation, back problems, knee discomfort, sprains and ligament injuries, and heel spur are attributed to side effects of defective footwear in the

market designed for the fashion concepts disregarding the human footwear interface and interaction. In recent years, designers and consumers have started to look beyond appearance and aesthetic requirements. Sizes of different parts of the feet and its skeleton have been of help in tracing human remains, although literature on this topic is scanty. Some workers have attempted sex determination from foot measurements,<sup>[1-3]</sup> shape of the foot,<sup>[4]</sup> and foot bones.<sup>[5,6]</sup> Few other workers correlated the height of the individual with the size of the feet in a small fraction of the population. The available literature is inadequate to infer any correlation between the height and the foot. The dimensions of the foot have been used for the determination of sex, age, and stature of the individual.<sup>[7]</sup> Foot anthropometry is also used for examination of the flatfoot<sup>[8]</sup> and sex in children.<sup>[9]</sup> Some workers used foot anthropometry for ergonomics and shoe designing for children. The present study is an effort to improve the

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morphometric data of foot in Western Uttar Pradesh and NCR Delhi children.

## Material and Methods

The present cross-sectional study was conducted on 250 children who belong to different parts of Western Uttar Pradesh and NCR Delhi. All the individuals included in the present study were healthy and free from congenital anomalies. A new methodology was used to collect the sample and measure the foot length and width. In the present study, the length and width of the feet along with the stature of the individual were measured. Age of the individuals ranged from 6 to 10 years. The foot was placed on a scanner connected to a computer through Photoshop software and scanned. The image of the foot is saved along with the ruler in the software. Measurements of the foot were done on the scanned pictures after calibrating the scale of the software [Figure 1]. To confirm the accuracy of the scale, same tracing of the foot was made on a paper and the measurements were cross-checked. The height of the person was measured from vertex to the floor while the individual was standing in an anatomical position. Foot length was measured from the tip of the second toe to the posterior most part of the heel in the scanned image [vertical line (L) in Figure 2]. Foot width was measured from the tip of the maximum lateral convexity to the tip of the maximum medial convexity of the foot in the scanned image [horizontal line (W) in Figure 2]. The observations were tabulated to find the correlation between the height of the individuals with the length and width of feet. The observations were statistically analyzed with the help of statistical program for the social sciences SPSS Version 20.0 by IBM (International Business Machines Corporation is an American multinational information technology company headquartered in Armonk, New York, with operations in over 170 countries) computer program to derive a possible formula regarding the height and foot measurements. Pearson's correlation coefficient was calculated to establish the correlation between the stature

and foot dimensions for the right and left feet separately. The significance of the result was tested using Student's *t*-test;  $P < 0.01$  was considered as statistically significant.

## Advantages of the present methodology

The present methodology is eco-friendly as we did not use paper for collecting the morphometric data.

The usage of Photoshop software eliminates human errors in measurements.

## Results

The present study deals with the observations on correlation of stature with foot measurements in 250 Western Uttar Pradesh and NCR Delhi children, aged between 6 and 10 years. Among them, 71 were aged 6 years, 26 members were aged 7 years, 41 members were aged 8 years, 77 members were aged 9 years, and 35 members were aged 10 years. The average height of the sample is 124.34 cm; the average foot measurements are 19.33, 19.3, 7.66, and 7.59 cm for the right foot length (RFL), left foot length (LFL), right foot width (RFW), and left foot width (LFW), respectively. When the average heights of individual age group children were measured, the average height of 6-year-old children was 116 cm, 7-year-old children was 119 cm, 8-year-old children was 126 cm, 9-year-old children was 129 cm, and 10-year-old children was 132 cm. When the average foot lengths of individual age group children were measured, the average foot length of 6-year-old children was 18.0 cm, 7-year-old children was 18.5 cm, 8-year-old children was 19.5 cm, 9-year-old children was 20 cm, and 10-year-old children was 20.5 cm. When the average foot widths of individual age group children were measured, the average foot width of 6-year-old children was 7.1 cm, 7-year-old children was 7.5 cm, 8-year-old children was 7.8 cm, 9-year-old children was 7.9 cm, and 10-year-old children was 7.9 cm. The values of foot length and foot width are the average of the right and left feet together.

Table 1 shows the number of sample, average heights, foot lengths, and foot widths.



Figure 1: How the scale of scanner (left) was calibrated with a scale (right)

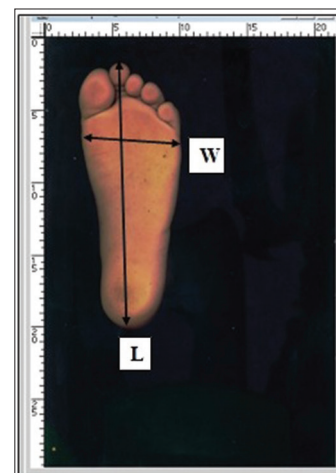


Figure 2: "L" represents foot length; "W" represents foot width

Statistical analysis shows that the stature ranges from 104 cm to 147 cm, and the mean height was 124.34 cm with a standard deviation of 8.94 cm; RFL ranges from 15.8 cm to 23.7 cm and the mean RFL was 19.33 cm with a standard deviation of 1.56 cm; LFL ranges from 15.5 cm to 23.7 cm and the mean LFL was 19.3 cm with a standard deviation of 1.56 cm; RFW ranges from 6.1 cm to 9.0 cm and the mean RFW was 7.66 cm with a standard deviation of 0.6 cm; and LFW ranges from 6.1 cm to 9.1 cm and the mean LFW was 7.59 cm with a standard deviation of 0.6 cm.

Table 2 shows the descriptive statistics of stature, the right, and left foot measurements.

The values obtained were statistically analyzed with the help of SPSS software and found the correlation coefficient values between various foot measurements and height. Foot lengths of both the right and left feet have a strong correlation to stature with a value of 0.736 (*r*) and *P* = 0.01. Foot width of the right feet has a good correlation to stature with a value of 0.591 (*r*) and *P* = 0.01. Foot width of the left feet has a good correlation coefficient to stature with a value of 0.588 (*r*) and *P* = 0.01. Although the measurements of the foot are significantly correlated with stature, the level of significance is higher for the length of both right and left feet.

Table 3 shows the Pearson's correlation coefficient "*r*" and their significance level "*P*" between stature and bilateral foot measurements.

After analyzing the sample statistically, we tried to formulate the linear regression formulas to estimate the stature from different measurements of the foot. The linear regression formulas are as follows:

- Stature = 42.643+ (4.2254 × RFL)
- Stature = 43.263+ (4.2025 × LFL)
- Stature = 56.189+ (8.8943 × RFW)
- Stature = 58.045+ (8.7273 × LFW).

Table 4 shows the linear regression formulae.

## Discussion

In the present study, it was observed that the average increase in height per 1 year is 3 cm, but the children who are aged 8 years show more growth when compared with other children. The increase in the foot length is 0.5 cm/year; here also, children who are aged 8 years show more growth when compared with other children. On an average, for every 3 cm increase in height, 0.5 cm increase in foot length was observed; foot width did not show such correlation. No differences were found when foot length of the right and left feet were analyzed with a correlation coefficient value of 0.736. Although there is a difference in the correlation coefficient values of foot width and height, the difference is very less with values 0.591 for the right side and 0.588 for the left side (where the difference is 0.003). Few workers reported right-sided foot measurements are dominant;<sup>[10,11]</sup> few others reported left-sided foot

**Table 1: Average heights, foot lengths, and foot widths of the sample**

Age (years)	Number of sample	Average height (cm)	Average foot length (cm)	Average foot width (cm)
6	71	116	18	7.1
7	26	119	18.5	7.5
8	41	126	19.5	7.8
9	77	129	20	7.9
10	35	132	20.5	7.9

**Table 2: Descriptive statistics of stature, the right, and left foot measurements**

Variant	Maximum value (cm)	Minimum value (cm)	Mean value±SD	SE
Height	147	104	124.34±8.94	0.57
RFL	23.7	15.8	19.33±1.56	0.098
LFL	23.7	15.5	19.3±1.56	0.099
RFW	9	6.1	7.66±0.6	0.038
LFW	9.1	6.1	7.59±0.6	0.038

RFL: Right foot length, LFL: Left foot length, RFW: Right foot width, LFW: Left foot width, SD: Standard deviation, SE: Standard error

**Table 3: Pearson's correlation coefficient "*r*" and their significance level "*P*" between stature and bilateral foot measurements**

Correlation between	<i>r</i>	<i>P</i>
Stature and RFL	0.736	0.01
Stature and LFL	0.736	0.01
Stature and RFW	0.591	0.01
Stature and LFW	0.588	0.01

*r*: Correlation coefficient, *P*: Probability value, RFL: Right foot length, LFL: Left foot length, RFW: Right foot width, LFW: Left foot width

**Table 4: The linear regression formulae**

Variable	Linear regression equations for estimation of stature
RFL	42.643 + (4.2254×RFL)
LFL	43.263 + (4.2025×LFL)
RFW	56.189 + (8.8943×RFW)
LFW	58.045 + (8.7273×LFW)

RFL: Right foot length, LFL: Left foot length, RFW: Right foot width, LFW: Left foot width

measurements are dominant.<sup>[1,2]</sup> Some workers did not find the difference<sup>[12]</sup> which is similar with the present study.

## Conclusion

Stature is an important parameter in determining the partial identity of unidentified bodies and dismembered remains. Means to establish stature are numerous, and their significance lies in simplicity of measurement, applicability, and accuracy in prediction. In the present study, though all the measurements of feet are significantly correlated with stature, the level of

significance is higher for the length of both right and left feet; so, stature can be estimated accurately with the help of foot length. We also worked on growth pattern comparisons of foot measurements and stature, which is very significant in determining the growth rate of children. According to the present study, there should be a 3 cm increase in stature and 0.5 cm increase in foot length for every year in children who are aged between 6 and 10 years. If they are having such growth rate, it can be considered normal.

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### Conflicts of interest

There are no conflicts of interest.

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