Original Article

Stature Estimation from Foot Radiographs of North Indian Population

Vishram Singh, V. Chakradhar[1], Yogesh Yadav, Rashi Singh[2]

Department of Anatomy, Santosh Medical College, [1]Department of Anatomy, Santosh University, [2]Department of Pediatric and Preventive Dentistry, Santosh Dental College, Ghaziabad, Uttar Pradesh, India

Abstract

Introduction: Stature is necessary for medical, nutritional assessment, age, and race identification. The present study aims to measure the radiographic foot angles in different age groups of the North Indian population, National Capital Region, New Delhi, correlating it with the height of the individual. **Material and Methods:** The study was done for 1 year from September 2016 to November 2017 carried out on 257 individuals. Calcaneal pitch angle (CPA), talohorizontal angle, talocalcaneal angle (TCA), talo-first metatarsal angle (TFMA), and radiological foot length (RFL) were measured using radiographs of all the patients. **Results:** Results concluded that, among all the parameters, the radiographic length of the left and right foot was more correlated followed by TCA on the left side and right side with the stature. The correlation equation came to be Y = 69.97 + 4.18*X (Y = height and X = radiographic foot length for the right foot). The correlation equation was Y = 72.7 + 4.05*X (Y = height and X = Radiographic foot length for the left foot). **Discussion and Conclusion:** There is a positive correlation for talocalcaneal, TFMAs, and RFL on both sides with the stature of the patient. CPA and talohorizontal angles were negatively correlated with the stature. More studies involving a large number of patients could help to draw a valid conclusion.

Keywords: *Calcaneal pitch angle, correlation, foot length, foot radiograph, stature estimation, talar line, talocalcaneal angle*

Introduction

Stature is necessary for medical, nutritional assessment, age, and race identification. It is also used in physical anthropology and forensic medicine. The main question that strikes when people find remnants of the skeleton is, "what would have been the height of this person when he was alive?" To answer this question, researchers have taken an interest in determining the height of an individual. It is possible to estimate the height by two methods-anatomical and mathematical methods.[1] The mathematical method considers the regression coefficients derived from the measurements of many bones in the body. Foot angle was considered to be one of the reliable dimensions for estimating the stature of an individual. Determining the height by radiological evaluation is essential during natural disasters, mass deaths, and in disintegrated bodies where long bones cannot be found. When we look at the past literature, Abrahamyan *et al*.[2] have measured the height using the whole-body dual-energy X-ray absorptiometry scans of bones such as humerus, radius, femur, and tibia in children. Previously, few scientists like Coster[3] measured angulations between the foot arch bones on X-ray in an attempt to find out the correct treatment procedure for conditions like a flat foot. Lateral radiographs of the feet obtained for each individual in a bilateral standing position maintaining identical weights on both feet helps to estimate stature. Gwani *et al*.[4] used truncated foot length and full foot length on the lateral radiographs of the foot for assessing the stature. He used the foot length, excluding the phalanges for more accurate stature estimation. Karaman *et al*.[5] used the radiographs of the hand and wrist to identify the stature by measuring the length of metacarpals and metatarsals. Source of information on the estimation of stature through radiographs can be obtained using the atlas of Hoerr *et al*.[6] which presents various radiographic plates of the foot and ankle of children of known age and sex. This atlas has been in existence for the past 50 years. The present study was designed to measure the radiographic foot angles in different age groups of the North Indian population, both male and female patients belonging to the National Capital Region (NCR), New Delhi, correlating it with the height of

How to cite this article: Singh V, Chakradhar V, Yadav Y, Singh R. Stature estimation from foot radiographs of North Indian population. J Anat Soc India 2020;68:274-8.

Article Info

Received: 20 November 2019
Accepted: 13 December 2019
Available online: 28 February 2020

Address for correspondence:
Prof. Vishram Singh, Department of Anatomy, Santosh Medical College, Ghaziabad, Uttar Pradesh, India.
E-mail: drvishramsingh@gmail.com

Access this article online

Website: www.jasi.org.in
DOI: 10.4103/JASI.JASI_229_19
Quick Response Code:

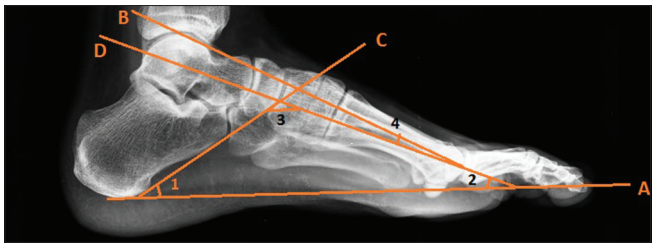

Figure 1: Radiographic picture showing four lines and angles

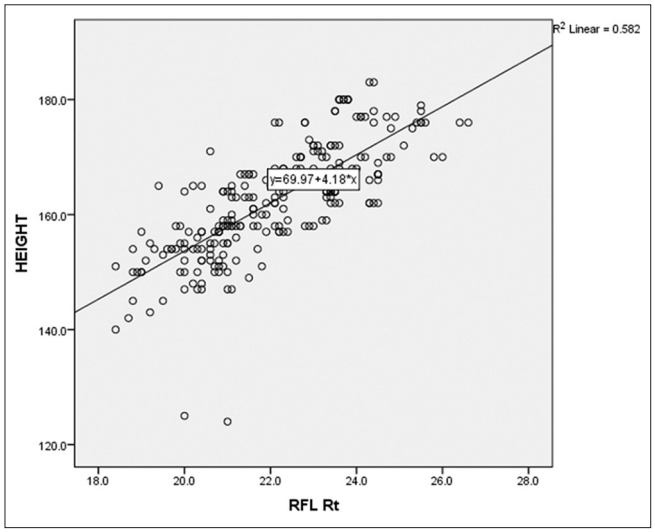

Figure 3: Correlation between height and radiological foot length right

the individual. This cross-sectional, community-based study may aid to improve the insufficiency of radiographic data of foot in the North Indian population. The added knowledge will be of immense value to forensic specialists, podiatrists, and orthopedic doctors.

Material and Methods

The present study was a cross-sectional, community-based, observational, screening, and diagnostic study carried out on 257 individuals in the Department of Anatomy, Santosh Medical College NCR, New Delhi, in the duration of 1 year from September 2016 to November 2017.

Inclusion criteria

Male and female Indians in the age group of 21–25 years were included in the study.

Exclusion criteria

1. Pregnant, breastfeeding women
2. Patients suffering from chronic liver, kidney, and heart disorders
3. Patients with a history of foot fracture and bony deformities were excluded from the study.

Ethical considerations

Before conducting the study, institutional ethical committee

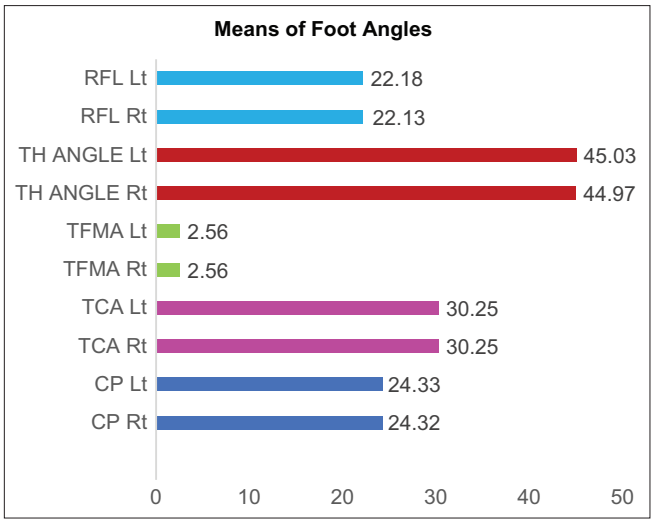

Figure 2: Radiological parameters in group

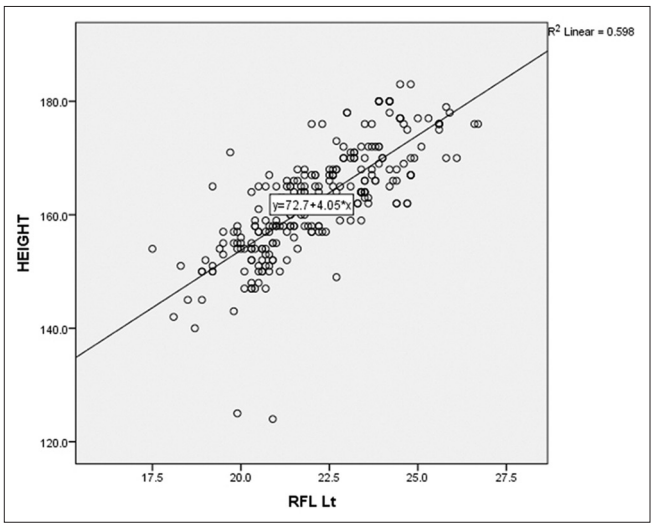

Figure 4: Correlation between height and radiological foot length left

approval was obtained. All the procedures followed in the current study were in accordance with the ethical standards of the institutional ethical committee and with the ethical principles of the Helsinki Declaration of 1975,[7] updated in 2013. The objectives, procedure, and advantages of the study were explained to all patients, and written informed consent in the local language was taken through their signature. Radiographs were taken in the separate X-ray room, between 10 am and 1 pm, daily for the patient's convenience. The study was noninvasive. Environment with minimal interference was maintained to prevent errors of measurement. The patient was asked to report if there is any discomfort. We have maintained strict confidentiality of all patients by desisting from mentioning their names, initials, address, phone numbers, or hospital numbers.

Methodology

Patients involved in the study were asked to fill a questionnaire about demographic characteristics such as

Table 1: Foot parameters of patients

	Height	CP right	CP left	TCA right	TCA left	TFMA right	TFMA left	THA right	THA left	RFL right	RFL left
Average	162.6	24.3	24.33	30.2	30.2	2.56	2.56	44.9	45.0	22.1	22.1
SD	9.5	1.25	1.25	1.9	1.9	0.96	0.96	5.47	5.49	1.73	1.81
Maximum	183	26.9	26.9	33.6	33.6	4.6	4.5	55	56	26.6	26.7
Minimum	144	22.5	22.58	25.9	25.9	1	1	37	37	18.4	17.5
Correlation coefficient		−0.09	−0.091	0.077	0.077	0.058	0.059	−0.019	−0.020	0.76	0.773

TC: Talocalcaneal angle, CP: Calcaneal pitch, TFMA: Talo-first metatarsal angle, THA: Talohorizontal angle, RFL: Radiological foot length, SD: Standard deviation

age, residing place, contact number, and occupation before taking the X-rays. As the radiological examination should be done after completion of the skeletal development, the lower age limit of the study was determined as 20 years of age.

The following four lines as shown in Figure 1 helps to find the angles mentioned above:

A. Horizontal line is the line drawn between the most plantar process of the calcaneus and the metatarsal head of the fifth metatarsal[7]
B. Metatarsal line is the line joining the centers of the superior and inferior cortices of the first metatarsal[7]
C. Calcaneal line is drawn along the plantar surface of the calcaneus[7]
D. Talar line is the longitudinal axis of the talus joining the points marked in the middle of the superior and inferior parts of the distal and proximal talus.[7]

The following parameters were estimated in radiographs:

1. Calcaneal pitch angle (CPA[8-12]
2. Talohorizontal angle (THA)[8-12]
3. Talocalcaneal angle (TCA)[8-12]
4. Talo-first metatarsal angle (TFMA)[8]
5. Radiological foot length (RFL).[8]

CPA[9-12] is used in the diagnosis and severity grading at X-ray of the flat feet in adults. It is the angle of the calcaneus and the inferior aspect of the foot, with various sources giving various reference points.

The first line forming the angle is defined as the calcaneal inclination axis, extending from the calcaneus by the inferior portion of the calcaneocuboid joint to the inferior border of the calcaneus[9] or tangential to the inferior distal border of the calcaneus.[10] The second line is defined as extending one of the above lines to the inferior border of the head of the fifth metatarsal bone or the inferior aspect of the medial sesamoid bone of flexor hallucis longus.[11] or parallel to the ground.[12-14]

Talocalcaneal angle[15,16] is also called as the kite angle. It is the angle between lines drawn down the axis of the talus and calcaneus. This angle may vary depending on the position of the calcaneus under the talus and stiffness of the foot ligaments. The midtalar line should pass through the base of the first metatarsal, and the mid-calcaneal line should pass through the base of the fourth metatarsal. Normal TCA is 25–40°. TFMA:[15] this angle is formed between the long axis of the talus and first metatarsal on a weight-bearing lateral view. The mean value of the length of the foot, lateral TCA, TFMA, THA, and CPA were measured. The length of the foot was measured on the radiograph with the help of picture archiving and communication system (PACS) software developed and manufactured by Medical imaging and Technology Alliance (MITA) Arlington, USA; This software is a PACS used for medical imaging technology that provides easy storage and convenient access to images from various modalities.[17]

The following correlation coefficients were calculated as follows:

1. Correlation coefficient for CPA and height for the right and left foot
2. Correlation coefficient for THA and height for the right and left foot
3. Correlation coefficient for TCA and height for the right and left foot
4. Correlation coefficient for TFMA and height for the right and left foot
5. Correlation coefficient for RFL and height for the right and left foot.

Results

There were no dropouts during the period of the study.

Statistics

All the readings were statistically analyzed using 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) for windows statistical package program to find out the correlation between the angles and stature. Table 1 shows the descriptive statistics of different angles of foot from radiographs and their correlation with stature.

Participants (n = 257) in the age group of 21–25 years have a mean height of 162.576 cm with a standard deviation of 9.4820. Their minimum height was 144 cm, and the maximum height was 183 cm, which implies the range was large (144–183 cm).

Mean angles obtained in this study are shown in the Figure 2. Mean calcaneal pitch angles of both sides of the foot were almost identical. They showed a slight negative correlation with the height of the patient. Hence, they may not help to assess the stature of a person. Mean talocalcaneal both the right and left side are almost equal and show a positive correlation with the height of the patient. Hence, they can be used to estimate stature. Mean TFMA of the right foot and left foot shows a slight positive correlation with the stature. Radiographic foot length is more for the left foot compared to the right foot. The right and left radiographic foot lengths were having a positive correlation with the height of the patient, which implies they can help to estimate the stature. Figures 3 and 4 show positive correlation between stature and radiological foot length. Similarly, the mean THA on the left side is more the right side, and they were negatively correlated with the height of the person. Hence, they cannot be used to assess the stature of a person. Among all the parameters, the radiographic length of the left and right foot was more correlated followed by TCA on the left side and right side with the stature. The current study involved only 257 individuals. More studies are required to draw a confirmed conclusion.

The following graph shows a positive correlation between height and RFL of the right foot.

The correlation equation is Y = 69.97 + 4.18*X (Y = height and X = RFL).

The following graph shows a positive correlation between height and RFL of the left foot.

The correlation equation is Y = 72.7 + 4.05*X (Y = height and X = RFL).

Discussion

The results of the current study prove that there is no statistically significant correlation between the person's height and his right and left foot angles. Moreover, a positive correlation exists only for RFL, talocalcaneal, and TFMAs and a person's height. Hence, radiometric data may be used to estimate a person's stature. Although variations occur across various races, due to an individual's genetic makeup and nutrition, the regression formulas obtained from this study may be applied to the general population in India. Sample population in this study includes patients and the general population attending the tertiary care center attached to Santosh Medical College. Diversified people will be visiting the hospital, on which only a few studies were conducted earlier. Hence, the current study helped in providing data for further studies. In our study, we have not done stature estimation with respect to genders. The previous study done by Krishnan K[18] concluded statistically higher mean values among male patients, which can be attributed to the early maturity of female patients. The average height of the person is maximum in the age group of 21-25 years. After 25 years, the height of the person starts declining gradually. Hence, we have taken radiographs for patients aged up to 25 years. In the current study, the mean right CPA came to be 24.32 and mean left CPA to be 24.33, which is in contrast to the study done by Lee *et al*.[12] among Koreans. The mean talus of first metatarsal angle was 0 ± 6.9°, the mean THA was 25.8 ± 4.5°, and the mean CPA was 23.9 ± 5.1°. The data and the results obtained in the present study are the first-ever documented radiographic work on the general population of Ghaziabad, to the best of my knowledge. Since the calculated heights are unique for the NCR, New Delhi population, the findings may not be used outside that population.

Limitations of the study

1. One of the drawbacks of the current study is regression equations may provide more erroneous results for taller and shorter individuals by the mathematical method
2. Assessment of stature with respect to gender was not done, and other radiographic angles, hand length, and handbreadth were not assessed
3. More accurate results can be obtained by enrolling a greater number of participants into the study and conducting the study for a longer duration of time.

Recommendations for future studies

1. To gather more information on other parameters to assess the stature
2. Comparison between hand and foot parameters related to the stature and to assess which is more correlated in male and female patients.

Conclusion

Average Height of the person is maximum in the age group 21-25 years. After 25 years, the height of the person starts declining gradually. Radiological foot length can be used to estimate the stature of a person among all the radiological measurements.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Stature Estimation. Available from: https://www.nist.gov/document/swganthstatureestimationrpdf. [Last accessed on 2018 Sep 19].
2. Abrahamyan DO, Gazarian A, Braillon PM. Estimation of stature and length of limb segments in children and adolescents from whole-body dual-energy X-ray absorptiometry scans. Pediatr Radiol 2008;38:311-5.
3. Coster JS, Graziano J, Yoon J, Rolle M. Foot Facts: The Role of Foot X-Rays. Alexandria Podiatry Associates 1-2. Available

from: http://alexandriapodiatry.org/text/foot_xrays.pdf. [Last accessed on 2018 Oct 18.]

4. Gwani AS, Salihu AT, Garba IS, Rufa'i AA. Estimation of stature from radiographic measurement of foot dimensions: Truncated foot length may be more reliable than full foot length. J Forensic Leg Med 2017;46:53-7.
5. Karaman AG, Teke HY, Gumay I, Dogan B, Bilge Y. Height estimation using anthropometric measurements on X-rays of wrist and metacarpal bones. Int J Bilo Anthropol 2008;2:1-8.
6. Hoerr NL, Pyle SI, Francis CC. Radiographic Atlas of Skeletal Development of the Foot and Ankle. Springfield, IL: Charles C. Thomas; 1962.
7. The World Medical Association-WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects. Available from: https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/. [Last accessed on 2018 Sep 27].
8. Ozaslan A, Karadayi B, Kolusayin M, Kaya A, Afsin H. Predictive role of hand and foot dimensions in stature estimation. Rom J Legal Med 2012;20:41-6.
9. Sinacore DR, Gutekunst DJ, Hastings MK, Strube MJ, Bohnert KL, Prior FW, *et al*. Neuropathic midfoot deformity: Associations with ankle and subtalar joint motion. J Foot Ankle Res 2013;6:11.
10. Crim JR, Manaster BJ, Rosenberg ZS. Imaging Anatomy: Knee, Ankle, Foot. Philadelphia, PA: Elsevier; 2017. p. 468.
11. Wiesel SW. Calcaneal pitch angle segment. Operative Techniques in Orthopaedic Surgery (INTERNATIONAL STANDARD BOOK NUMBER (ISBN): 9781496314680) Lippincott Williams and Wilkins 2015.
12. Lee YK, Yim SJ, Lee SH, Park CH, Lee SH. The talus1st metatarsal angle of young men in Korea. Korean Foot Ankle Soc 2010;14:161-4.
13. Bourdet C, Seringe R, Adamsbaum C, Glorion C, Wicart P. Flatfoot in children and adolescents. Analysis of imaging findings and therapeutic implications. Orthop Traumatol Surg Res 2013;99:80-7.
14. Ippolito E, Fraracci L, Farsetti P, De Maio F. Validity of the anteroposterior talocalcaneal angle to assess congenital clubfoot correction. AJR Am J Roentgenol 2004;182:1279-82.
15. Flores DV, Mejía Gómez C, Fernández Hernando M, Davis MA, Pathria MN. Adult acquired flatfoot deformity: Anatomy, biomechanics, staging, and imaging findings. Radiographics 2019;39:1437-60.
16. Arunakul M, Amendola A, Gao Y, Goetz JE, Femino JE, Phisitkul P. Tripod index. Foot Ankle Int 2013;34:1411-20.
17. Choplin RH, Boehme JM 2nd, Maynard CD. Picture archiving and communication systems: an overview. Radiographics 1992;12:1279.
18. Krishan K, Sharma A. Estimation of stature from dimensions of hands and feet in a North Indian population. J Forensic Leg Med 2007;14:327-32.