



Stature estimation from the lengths of the growing foot—A study on North Indian adolescents[☆]

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ABSTRACT

Background and aims: Stature estimation is considered as one of the basic parameters of the investigation process in unknown and commingled human remains in medico-legal case work. Race, age and sex are the other parameters which help in this process. Stature estimation is of the utmost importance as it completes the biological profile of a person along with the other three parameters of identification. The present research is intended to formulate standards for stature estimation from foot dimensions in adolescent males from North India and study the pattern of foot growth during the growing years.

Methods: 154 male adolescents from the Northern part of India were included in the study. Besides stature, five anthropometric measurements that included the length of the foot from each toe (T1, T2, T3, T4, and T5 respectively) to pternion were measured on each foot. The data was analyzed statistically using Student's *t*-test, Pearson's correlation, linear and multiple regression analysis for estimation of stature and growth of foot during ages 13–18 years.

Results: Correlation coefficients between stature and all the foot measurements were found to be highly significant and positively correlated. Linear regression models and multiple regression models (with age as a co-variable) were derived for estimation of stature from the different measurements of the foot. Multiple regression models (with age as a co-variable) estimate stature with greater accuracy than the regression models for 13–18 years age group.

Conclusions: The study shows the growth pattern of feet in North Indian adolescents and indicates that anthropometric measurements of the foot and its segments are valuable in estimation of stature in growing individuals of that population.

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1. Background

The human foot has been the focus of many diverse areas of research in the past that include studies on diabetes and orthopedic problems, palaeoanthropological and evolutionary studies, industrial ergonomics, anatomical studies, anthropological studies and forensic investigations on the foot. The forensic identification from the foot and its parts is important as there is an increased likelihood of the recovery of feet (often enclosed in shoes) separated from the body in mass disasters such as terrorists' attacks, mass murders, high power explosions and bomb blasts, air plane

crashes and other high impact transportation mishaps, tsunamis, floods, and earthquakes [1].

Numerous studies have focused on the forensic significance of the human foot; radiographic analysis of foot has been conducted [2,3], foot impressions have been studied [4–6], and foot bones [7–11] and anthropometric measurements of foot are used for estimation of sex and stature [12–20]. A few studies in the past have been conducted on the correlation of height and weight with foot anthropometry [21,22]. In addition various individualistic and unique features of the foot and footprints have been studied for the establishment of identity of an individual in forensic case work [23–28]. Radiographic comparisons of the foot and ankle are shown to be helpful in identifying the dead through forensic examinations [29–33].

During the forensic identification of dismembered remains, estimation of ancestry, sex, age, and stature facilitate in narrowing down of the pool of possible victim matches in the forensic investigation process and help to establish the identity of an individual. The stature can be estimated from skeletal remains and body parts

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through the established relationship between stature and different parts of the body [34–36]. Estimation of stature is used in conjunction with other factors of personal identification whenever unknown human remains are brought for forensic examination and stature estimation is thus, an important parameter in forensic investigation.

Previous studies reveal that the human foot, its bones and its impressions can successfully be used in the estimation of stature in forensic and legal examinations. These studies however, are restricted to estimation of stature from maximum foot length and breadth and most of these studies have been conducted on adult populations. Stature estimation from foot dimensions in adolescents is a challenging task. In this context, it is vital to understand the growth pattern in foot dimensions during the period of growth in an individual. Earlier studies suggest that growth of the foot is completed by 16 years of age in males [37,38]. These studies, however, were performed more than 50 years ago on American population. The present research is intended to formulate standards for stature estimation from foot dimensions in adolescent males from North India and to study the pattern of foot growth during the growing years. The present research also uses additional foot dimensions other than the maximum foot length alone as used in earlier studies on stature estimation from foot length in adult populations that can be useful when a part of foot is brought for examination.

2. Materials and methods

2.1. Sample

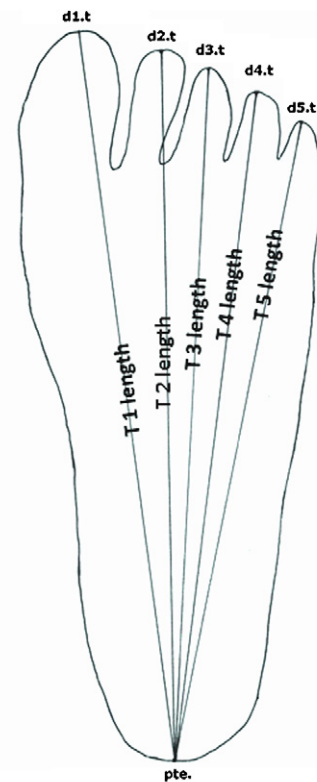
The present research was conducted in a designated region of Tehsil Kalka, District Panchkula in the Haryana state of North India and this study is a part of a larger study [39,40] conducted in this region. The data for the study comprise of 154 North Indian adolescent males aged between 13 and 18 years [mean age = 15.8 ± 1.7 years]. The participants were taken from the educational institutions located in the villages of Nanakpur, Marranwala and Bassolan. Healthy individuals without any deformity of the foot or spine were included in the study. Permission to conduct the study was taken from the principals of the schools involved. The participants were informed about the study in their classrooms and were advised that the data would be used for research purposes. Informed consent to participation was taken from the participants.

2.2. Methodology

The data consisted of a set of measurements that included stature and length of the foot from each toe to the back of the heel (T1, T2, T3, T4, and T5 respectively). All the measurements were taken following standard procedures and landmarks defined by Krishan [1], Robbins [24] and Vallois [41] using standard instruments; anthropometric rod and anthropometric rod compass. All the anthropometric measurements taken on the foot are depicted in Fig. 1 and the different landmarks on the foot are described in Table 1. All the measurements were recorded to the nearest millimeter. The following measurements and techniques were used:

2.2.1. Stature

Stature is the vertical distance between the point vertex (the highest point on the head when the head is held in the Frankfurt Horizontal plane) and the floor. Each subject was asked to stand erect against the wall with their hands hanging down, their feet unshod and parallel or slightly divergent, with the head in the Frankfurt Horizontal Plane and with their heads bare. The stature



pte. – pterion; d1.t – Digit 1, terminal; d2.t – Digit 2, terminal; d3.t – Digit 3, terminal; d4.t – Digit 4, terminal; d5.t – Digit 5, terminal

Fig. 1. Measurements and landmarks on the human foot.

was then recorded using the anthropometric rod. No pressure was exerted as this is a contact measurement.

2.2.2. Foot length measurements

For recording foot measurements, each subject was made to stand with the feet slightly apart and with equal pressure on both feet. The anthropometric rod compass was horizontally placed on the landmarks and the measurements were taken.

T1 length: Between pterion (pte) and the most distal part of the first toe (d1.t).

T2 length: Between pterion (pte) and the most distal part of the second toe (d2.t).

T3 length: Between pterion (pte) and the most distal part of the third toe (d3.t).

T4 length: Between pterion (pte) and the most distal part of the fourth toe (d4.t).

T5 length: Between pterion (pte) and the most distal part of the fifth toe (d5.t).

Technique for taking T1 length has been depicted in Fig. 2; likewise, other measurements were taken on the foot.

2.3. Technical error of measurement

While conducting the present study, the technical error of the measurement and intra-observer error inherent in anthropometry were taken into consideration. Technical, inter-observer and intra-observer errors can have a substantial effect on accuracy and reliability which in the practice of forensic science can be detrimental. While collecting field data, the instruments were regularly checked for accuracy. All the measurements were taken by a trained physical anthropologist (NP). Before beginning the data collection,

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