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Stature estimation from the dimensions of foot in males

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Abstract: Stature estimation is a commonly used parameter in identification searched by medico-legal experts and forensic anthropologists. Examination of footprints provides important evidence in a crime scene investigation and helps in estimation of stature of a criminal. The present study examines the relationship between stature and foot dimensions among a diverse population group. To estimate stature; measurements of foot length (FL), foot breadth (FB) were used in this study. Measurements were obtained from 250 volunteers. The best correlation value were detected in foot dimensions as FL variable for males r=0.575. Lengths measurements belong to foot dimensions were more useful parameters than breadth measurements of those in stature estimation.

Key words: Forensic anthropology, identification, stature estimation, foot dimensions

Genç Erkeklerde Ayak Boyutlarından Boy Uzunluğunun Tahmini

Öz: Boy uzunluğunun tahmini adlî tıp uzmanları ve adlî antropologlar tarafından kimlik tespitinde yaygın bir şekilde kullanılmaktadır. Ayak izleri olay yeri incelemesinde önemli kanıtlar sağlayabilmekte, boy uzunluğunun tespit edilmesi ise kriminal olayları aydınlatabilmektedir. Elinizdeki çalışmada, farklı kökenden insanların yaşadığı bir grupta ayak boyutları ile boy uzunluğu arasındaki ilişkiler ele alınmaktadır. Boy uzunluğunu tahmin etmek için ayak uzunluğu (AU) ve ayak genişliği (AG) ölçüleri kullanılmıştır. Ölçüler 250 gönüllü denek üzerinde alınmıştır. Boy uzunluğu ile daha yüksek bir korelasyon gösteren değişken ayak uzunluğudur (r=0,575). Boy uzunluğunu tahmin etmede ayağa ilişkin uzunluk ölçülerinin daha başarılı olduğu sonucuna ulaşılmıştır.

Anahtar Kelimeler: Adli antropoloji, kimlik tespiti, boy tahmini, ayak boyutları

Introduction

Estimation of stature from complete skeleton and decomposing bodies is a recurring theme in physical anthropology and forensic science. Analysis of footprints helps in estimation of an individual's stature because of existence of strong positive correlation between one's stature and foot size; the footprints are also considered as indicators of skeletal and body structure of a person.

Certain long bones and appendages can be aptly used in the calculation of height of a person. Many studies have shown the correlation of stature with body appendages (Duyar and Pelin, 2003; Pelin and Duyar, 2003; Jasuja and Singh, 2004; Sanli et al., 2005; Ozden et al., 2005; Krishan et al., 2007; Patel et al., 2007; Agnihotri et al., 2007; Rastogi et al, 2008; Sen et al., 2008; Chavan et al., 2009) and with long bones (Singh et al., 1951; Trotter and Gleser, 1952; Athwale, 1963; Shroff et al., 1979; Sjovold, 1990; Hauser et al., 2005; Musgrave and Harneja, 2005; Duyar et al., 2006; Bhavna and Nath, 2007; Abrahamyan et al., 2008; Bhavna and Nath, 2009; Duyar and Pelin, 2010; Sargın et al., 2012).

In the past, various other studies have been conducted on estimation of stature from foot and footprints (Robbins, 1984, 1985, 1986; Giles et al., 1991; Gordon et al., 1992; Jasuja et al., 1993; Barker et al., 1998; Krishan, 2002; Krishan et al., 2002, 2007). In aspect of forensics it is crucial in description of suspects from palms and foot prints in crime scenes (Krishan, 2008; Krishan et al., 2007; Kanchan et al., 2008). Earlier studies by Robbins (1984, 1986), Barker et al. (1998), Topinard (1876), Martin (1928), Martin and Saller (1959), Pales (1976), Jasuja (1987) provide a number of foot length/stature percentages for various populations. Some studies (Robbins, 1986; Jasuja, 1987; Sharma et al., 1978) have derived multiplication factors calculated by dividing stature by a foot/footprint measurement. However, these methods result in very high estimation error. Later on, various authors made use of regression equations (Krishan, 2002; Krishan et al., 2002; Jasuja, 1987; Sharma et al., 1978; Philip, 1990; Ozden et al., 2005; Atamtürk and Duyar, 2008) in estimating stature from foot/footprint dimensions

For stature estimation researches, different nutrition types and physical activities may cause variations in populations. Many studies are successfully performed on this topic despite a wide range of ethnics and races through the populations. In this study, it was aimed to evaluate the predictive role of foot dimensions in stature estimation.

Material and Methods

The present study was conducted on 250 males in the age group 18-23 years selected from various visitors to Lady Hardinge Medical College and Asst. Hospital, New Delhi, India. Height and foot measurements were done in the Department of Forensic Medicine. After that the results were subjected to statistical analysis. The subjects were apparently healthy with no obvious bony deformity that could affect the scientific observations. The maximum foot length and foot breadth of the volunteers was measured. The techniques employed were:

Foot Length – It was taken with the help of sliding callipers as straight distance between most posterior projecting points on heel to the most anterior projecting point of 1st or 2nd toe whichever is longer with the foot stretched fully.

Foot Breadth – Sliding callipers were used to measure the foot breadth as a straight line from most medially placed point on head of 1st metatarsal to most laterally placed point on head of 5th metatarsal. To minimize subjective error all measurements were taken thrice and mean was taken for statistical calculation on both sides separately.

The height of each individual was also noted as control. For this purpose the anthropometric rod was used. The subjects were made to stand erect unshod, with their back toward the point of anthropometric rod. The upper movable arc was brought down gently touching the maximum protuberance of the subject's head and the reading was taken.

The voluntary donors had cosmopolitan background in the sense that the sample comprised of subjects belonging to different parts of country. The age of 23 years was selected as the denominator in the age group because maximum body development has occurred by that time. Socioeconomic status, nutritional status, climatic influences and ethnic differences with other cultural influences were not taken into account.

Results

In males, stature varied from 150.0 cm to 183.5 cm with mean values of 167.08 cm and standard deviation of 5.70 cm and standard error is 0.362. Variation in dimensions of foot length and foot breadth in males is given in Tables 1.

Table 1. Descriptive statistics for stature and dimensions (cm) of foot in males

	Mean	SD	SE
Stature (cm) (x1)	167.08	5.70	0.362
Foot length (x2)	24.89	1.18	0.075
Foot breadth (x3)	9.59	0.56	0.035

Table 2. Correlation coefficient of stature and foot measurements in adult males along with their *t* and *P* values

	r	*T*	*P* value
Foot length	0.575	438.29	< 0.001
Foot breadth	0.316	447.40	< 0.001

Table 3. Simple and multiple regression equations to estimate stature (x1) (cm) from foot length (x2) in males

Simple regression equations	
Foot length (x2)	x1 = 2.779 x2 + 97.894
Foot breadth (x3)	x1 = 3.246 x3 + 135.942
Multiple regression equation	
Foot length (x2) and foot breadth (x3)	x1 = 97.788 + 2.771 x2 + 0.033 x3

Table 2 illustrates the correlation coefficients between stature and foot dimensions of feet on left and right sides in males. All the measurements exhibit statistically significant correlation with stature ($P < 0.01$). Correlation coefficients of the foot length measurements are higher in comparison to foot breath in males. Table 3 illustrate the simple and multiple regression equations to estimate stature from foot length and foot breadth.

Discussion

The present study was conducted in 250 males in the age group 18-23 years for the prediction of stature from foot measurements. The prediction can be of special importance in conditions where whole body is not available for identification.

The stature (height) in our study was 167.08 +/- 5.70 in males while it was 169.8 +/- 5.8 in Punjabi males (Jasuja et al., 1991), thus the height in our series was 2.72cm less but when compared with Turkish subjects, it was 4.8 cm less as evident from Ozaslan et al. (2002)'s study. But the SD, height in our study was lesser than Punjabi males (Jasuja et al., 1991) and the study by Ozaslan et al. (2002).

Standard deviation for foot length, in our study was lesser than that of Punjabi males (Jasuja et al., 1991); though mean foot length was lesser by 0.6 cm in our case, while both mean foot length and SD were equal to that of Ozaslan et al. (2002)'s study on Turkish subjects.

Mean foot breadth and SD in our study were lesser by 0.6 cm and 0.1 cm respectively in our case as compared to Jasuja et al. (1991). While it was 0.2 cm and +/- 0.2cm more as compared to Ozaslan et al. (2002)'s study conducted in Istanbul.

The standard deviation for height in our study was lesser than other studies is justified, greater the dispersion of values about the mean, larger the standard deviation. This resulted due to varied sample group, i.e. cosmopolitan nature of the sample group.

The correlation coefficient *r* between foot length (FL) and stature in Turkish males was 0.86, which was more than our study, while in Jasuja's study on Punjabi males *r* between

foot length and height was 0.68, more positive than our study while foot breadth (FB) and height *r* was 0.36, more positive than our study (Manisha et al., 2003)

In our study simple regression equations of stature and foot parameters had positive correlation as in the studies done by Ozaslan et al. (2002). Regression equation with multiplication factors derived by Jasuja et al. (1991) also showed positive correlation throughout. Stature estimation by using foot parameters (foot length and foot breadth) was done and it was found that by using multiple regression equations, stature can be calculated which is same as it was found in Gordon and Buikstra's study (1992), that models containing both foot length and foot breadth are significantly better than those containing only one parameter, confirming this finding (Gordon and Buikstra, 1992).

Similar to our results, Sanli (2005) also stated that the multiple linear regression model is best fitted than simple linear regression model for estimating height from foot length and hand length.

Krishan (2007) concluded that the dimensions of hands and feet can provide good reliability in estimation of stature. It was observed that the multiple regression equations reveal lower values of standard error of estimate (SEE) than the values given by linear regression equations. Interpretations suggest that the multiple regression equations are better indicators of stature estimation. This method of stature estimation can be used by law enforcement agencies and forensic scientists. The only precaution which must be taken into consideration is that these formulae are applicable to the population from which the data have been collected due to inherent population variations in these dimensions, which may be attributed to genetic and environmental factors like climate, nutrition etc. The results obtained in our study correlates with the previous studies.

Trotter and Glesser (1958), and Krogman (1962) were of the view that regression equations of more than one variant give more accurate estimation of stature than that of a single parameter. So it was found that our final multiple regression equations using two foot parameters were more accurate than simple regression equations.

Conclusion

The present study has established definite correlation between stature and foot-dimensions and also regression equations have been established. It will help in medico-legal cases in establishing identity of an individual when only some remains of the body are found as in accidents, mass disasters, bomb explosions, etc. If either of the measurement (foot length or total height) is known, the other can be calculated and this would be useful for anthropologists and forensic medicine experts. There are lot of variations in estimating stature from limb measurements among people of different region and/or ethnic groups. Further studies are required to collect the data from the different part of globe as the stature is the inherent characteristic of the individual, though influenced environmentally, therefore regional, simple and multiple regression equations can be of great value.

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