A model for reconstruction of personal stature based on the measurements of foot length

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ABSTRACT

Introduction: Height, like other phenotypic traits, is determined by a combination of genetic and environmental factors. It is sexually dimorphic and statistically more or less normally distributed. Estimation of stature from measurements of various long bones of the extremities has been attempted by many scientists with varying degree of accuracy. All such calculations depend on the fact that limbs exhibit consistent ratios relative to the total height of a person. These ratios are linked to age, sex and race.

Objectives: This study was carried out to investigate the relationship between personal stature and foot length among a group of male and female Sri Lankan adults and to derive a regression formula between the foot length and height of an individual.

Materials and Methods: A total of 210 medical students with an age span of 20-23 yrs. were included in the study. The foot length was measured using a sliding caliper capable of measuring to the nearest 0.01 mm. The height of the individual was measured standing erect, in anatomical position using a standing height measuring instrument.

Results: The differences of the foot length between the genders were found to be highly significant. A positive correlation between height and foot length was observed in both sexes and it was statistically significant. Regression equation for stature estimation was formulated using the foot lengths for both sexes.

Conclusion: The results indicate that foot length provides an accurate and reliable means in estimating the stature of an unknown individual. The regression formula derived in this study will be useful for anatomists, archeologists, anthropologists and forensic scientists.

Introduction

Height is sexually dimorphic and statistically more or less normally distributed. Height, like other phenotypic traits, is determined by a combination of genetic and environmental factors [1].

Estimation of stature from measurements of upper limb and lower limb bones has been attempted by many scientists with varying degree of accuracy [2,3,4,5]. Those studies resulted in establishing formulae for the estimation of height from long bones for the respective populations as the relationship between the two parameters vary according to age, sex and race. All such calculations depend on the fact that limbs exhibit consistent ratios relative to the total height of a person [6]. These ratios are linked to age, sex and race. Characteristic variations in proportions were shown to appear between major races and furthermore even among smaller ethnic groups [1,5]. It has been shown that the reliability of prediction of height from foot measurements was as high as that from long bones [7,8].

Consequently, the formulae designed to estimate stature from various anatomical dimensions in one population do not apply to another [1,2]. Furthermore, the need for the alternative formulae for the genders is also proved. The available data usually apply to Caucasians in Europe or North America. Only few studies of other racial groups exist which emphasize the need to establish standards in different ethnic populations. Therefore, this study was carried out to investigate the relationship between the foot length and stature among a group of male and female Sri Lankan adults.

Materials and Methods

This study was conducted on 210 medical students (118 male and 92 female) of the Faculty of Medicine, University of Ruhuna, Galle, Sri Lanka. The subjects were from different parts of the island belonging to different socio-economic status. The age of the subjects ranged from 20-23 yrs.

Foot length was defined as the direct distance from the most prominent point of the back of the heel to the tip of the big toe or to the tip of the second toe when the second toe is longer than the big toe. Foot lengths were taken independently on left and right side of each individual using a sliding caliper capable of measuring to the nearest 0.01 mm (Mitutoyo, Japan). The left foot was selected for measurements as per recommendation of the international agreement for paired measurements at Geneva (1912). The height of the individual was measured standing erect, in anatomical position using a standing height measuring instrument. All the measurements were taken at a fixed time between 14.00 – 16.30 hrs. to eliminate discrepancies due to diurnal variation. Furthermore, the measurements were recorded by the same person to minimize the errors in methodology. Results were analyzed using a statistical package SPSS (15th version).

Results

Regression equation for stature estimation was derived as follows;

For male: Height = 79.042 + 3.590 (foot length)

For females: Height = 65.549 + 3.944 (foot length)

For both male and female (combined): Height = 44.107 + 4.922 (foot length)

Foot lengths were taken independently on left and right side of each individual. Statistical analysis indicates that bilateral variation was insignificant for the measurements of foot length in both sexes. This result supports the findings of Krishan and Sharma, 2007 [9]. Various important parameters of the study are summarized in Table 1. Sex differences were found to be highly significant ($P<0.01$). Mean foot lengths of the male were significantly larger than that of the females for all ages ($P<0.01$).

Table 1 - Height, foot length, correlation coefficient, regression coefficient and value of constant in males and females.

Gender	Male	Female
Total number	140	118
Mean height ± SD (cm)	170.14 ± 5.22*	157.55 ± 5.75
Mean foot length ± SD (cm)	25.37 ± 1.05*	23.33 ± 1.05
Correlation Coefficient	0.724	0.719
Regression Coefficient	3.59	3.94
Value of Constant	79.04	65.54

** P < 0.01 when compared with the females.*

Discussion

The average height for each sex within a population is significantly different, with adult males on average being taller than adult females[1]. The results obtained in this study are in agreement with the above statement. It is stated that the gender difference in height may be attributed to sex chromosomal differences. Adult height between ethnic groups often differs significantly, for example, the average height of women from the Czech Republic is currently greater than that of men from Malawi. This may be due to genetic differences, to childhood lifestyle differences or to both.

Correlation coefficient between stature and foot length was found to be statistically significant and positive indicating a strong relationship between the two parameters. Regression equation for stature estimation was formulated using foot lengths and checked for their accuracy by comparing the estimated stature and the actual stature. The results indicate that foot length provides an accurate and reliable means in reconstructing the stature of an unknown individual. Furthermore, ossification of the bones of the foot occurs earlier than the other long bones of the lower extremity [1]. Therefore, even during adolescent age, height can be predicted more accurately from foot measurements than from the other long bones of the lower limb.

Results obtained from a study that attempted to reconstruct stature from various dimensions of feet demonstrated the highest correlation coefficient and the lowest standard error of estimation between the stature and foot length.

A correlation coefficient between height and foot length in Gujarat population was shown to be + 0.69 for males and + 0.70 for females [10]. The present study shows a correlation coefficient of +0.724 for males and + 0.719 for females which is most significant. These formulae are valid for the age group of the study population (i.e. 20-23 yrs).

Estimation of an individual's stature is an important parameter in forensic examinations and anthropological studies. Examination of foot prints provides important evidence in a crime scene investigation which helps in the estimation of stature of a criminal. Analysis of bare foot prints is often carried out in the developing countries where the footprints are frequently recovered at the crime scene [9]. Significant and positive correlation coefficient has been shown to exist between stature and measurements of foot print [11]. Taken together the evidence suggests that the relationship between foot length and stature is of practical use in medico legal, anthropology and archeological studies when such evidence provides the investigator the only opportunity to gauge that aspect of an individual's physical description.

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