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RESEARCH ARTICLE

ESTIMATION OF STATURE FROM RADIOLOGICALLY MEASURED HUMERUS LENGTH AMONG INDIAN ADULTS

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ABSTRACT

Estimation of stature is most common in forensic practice and is important both for legal and humanitarian reasons. Most of the time at scene of crime incomplete skeleton is usually available. Among anatomical and mathematical methods for stature estimation, mathematical method is more preferred as in this we can estimate living stature of individual from single bone. Though numbers of formulae and equation have been given for stature estimation by various workers. In India Pearson's formula is the most commonly used. Here we are estimating stature from radiologically measured humerus length from 107 Indian Adults of North Karnataka Bijapur city.

INTRODUCTION

The use of anthropometry in the field of forensic science and medicine dates back to 1882 when Alphonse Bertillon, a French police expert invented a system of criminal identification based on anthropometric measurements. Since then, anthropometry has continuously been used in forensic examinations of unknown commingled human remains. (Krogan *et al.,* 1986; Iscan 1998) Estimation of stature has a significant importance in the field of forensic anthropometry. Establishing the identity of an individual from mutilated, decomposed & amputated body fragments has become an important necessity in recent times due to natural disasters like earthquakes, tsunamis, cyclones, floods and man-made disasters like terror attacks, bomb blasts, mass accidents, wars, plane crashes etc.[3] Of the two basic methods of estimating living stature from long bones and body parts i.e. anatomical and mathematical method, the anatomic method is generally preferred over mathematical method when the complete skeleton or cadaver is available.[4,5] However, when mutilated remains and skeletal parts are referred for personal identification in forensic examinations, the forensic experts have to rely upon mathematical methods for stature estimation.[5]

It is obvious that the complete skeleton is rarely available at the scene of crime and thus the scientists have no choice than to use a relatively less effective method of stature reconstruction, i.e. mathematical method, due to its obvious advantage that it is workable even if a single long bone of the upper or the lower extremity is available for examination.[6] It is known that trunks and limbs exhibit consistent ratio among themselves and relative to total body height.[7] Although a variety of bones may be used for this purpose, best results are achieved using the long bones and long limb bones are more suitable for reconstructing the height of the body of an incomplete skeleton.[4,8,9,10,11,12] Limb bones are not the only useful tool for stature but their equations are still the most commonly used.[4,10]

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S[1]everal authors have developed limb bone-based regression formulae for different populations. Those devised by Trotter and Gleserin the United States and by Manouvrier in Europe have been widely used in forensic and anthropological works. Researchers such as Brothwell, Krogman and Iscan and Ubelaker have recommended the Trotter-Gleser equations as the most useful set of formulae.[13,14,15,1,16] In India, Pearson's formula is the most commonly used method to determine the height.[17] There are inter-racial and inter-geographical differences in measurement and their correlation with stature. What may be true for one race or region may not be true for the other. Even within our vast homeland of India there are many different ethnic populationswith each having their own variations.[3] Owing to the genetic and sex variation observed in different population groups in India, an attempt has been made to compute regression equations for the estimation of stature In this study, we are estimating stature from radiologically measured humerus lengths.

METHODS

107 Indian Adults of North Karnataka Bijapur city (male-70, females-37) aged 21 to 60 years referred to diagnostic and interventional radiological department from faculty of medicine, general surgery at Al-Ameen medical college, Bijapur were considered for the study. Patients with facture, pathology, or congenital abnormalities were excluded from the study. A sample of 60 adults (30 males, 30 females), with same age of the studied sample was used to assess the validity of the equation. After obtaining informed consent stature was measured and X-ray was done for humerus in all cases to obtain humerus maximum length (HML).

Stature

Standard anthropometric equipment (vertical anthrop meter) was employed for the stature measurements. Stature was measured with the subject standing bare-feet with his back to the anthrop meter, and with the head adjusted in such a way that the Frankfurt plane (upper border of the external auditory meatus is on a horizontal plane with the lower border of the eye). This plane should be parallel to the headboard when measuring the stature.[18]

Humerus Maximum Length (HML):

Humerus maximum length was measured by X-ray frontal views as the direct distance from the most superior point on the head of the humerus cut o²ff points (25th and 75th percentiles).[19]

Statistical analysis:

Data were analyzed using (SPSS) package 15. Linear regression analysis was performed in which HML was regressed against stature. Regression equations for stature estimation also was derived using HML. Pearson co-relation coefficient (r) and standard error of estimate (SEE) were obtained.[20] The resulted equations were validated and paired test was applied between actual and predicted mean differences were calculated. Percentile of distribution of stature were calculated with cut off points at 25th and 75th percentiles. Stature in the lower 25% of the distribution were regarded as "short", those in the upper 25% as "tall" and the remaining middle 50% was classified as "medium" percentiles of distribution of the HML was detected with the same cut off points (25th and 75th percentile).[19]

RESULTS

Table 1. Descriptive statistics for Age, Stature, Humerus Maximal Length

Variables	Male (n = 70)	Female (n = 37)	t p
Age Range -	21 – 60	21 - 60	0.482
Mean $\pm$ S.D.	35.60 $\pm$ 11.16	36.65 $\pm$ 10.5	0.631 NS
Stature Range	152 - 188	144 - 164	12.484
Mean $\pm$ S.D.	165.97 $\pm$ 6.72	153.49 $\pm$ 5.79	< 0.0001
Humerus length Range (cm)	28.20 - 39.60	28.50 - 35.10	6.265
Mean $\pm$ S.D.	33.85 $\pm$ 1.86	31.75 $\pm$ 1.73	< 0.0001

*significance at $p \leq 0.05$
NS: Not statistically significant

Table 1 shows mean, standard deviation (SD) and the range values for age stature and humerus maximum length of the studied population (70 males & 37 females). The mean ages were 35.60 ± 11.16 for males and 36.65 ± 10.5 for females. The age difference between the sexes was statistically insignificant.

The stature of studies adults ranged from 152 to 188 cms (mean 165.97 ± 6.72 for males, while that of females ranged from 144 to 164 cms (mean 153.49 ± 5.79) There was a significant difference between stature in males and females. Radiological examination revealed that the humerus maximum length is ranged from 28.20-39.60 cm in males and from 28.50-35.10 cm in females with a significant difference between males and females mean values 33.85$\pm$1.86 and 31.75$\pm$1.73 respectively (where P<0.0001).

Table 2. Correlation coefficient between stature and the radiologically, measured humerus maximal length

Variables	Male (n = 70) R	Male (n = 70) P	Female (n = 37) R	Female (n = 37) P
[3]Stature # humerus maximum length	0.811	< 0.00001	0.862	< 0.00001

* Significance at $p \leq 0.05$

Table 2 displays Pearson's correlation coefficient between stature and the radiologically measured humerus maximum length and it showed significant correlation with the stature. The correlation coefficient ofhumerus maximum length r=0.811 and P value <0.00001 for males and for females r = 0. 862 and P value <0.00001. The regression equation have been calculated by regression analysis of the data and the values of constant (a) is the regression coefficient of the dependent variable i.e stature and (b) is the regression coefficient of independent variable i.e any measurement out of the two studied parameters. Hence stature = a+bx, where x is the maximum length of humerus and regression equations have been calculated.

Table 3. Regression equation formulae for estimation of stature (in cm) from the radiological measured humerus maximum length (HML)

Sex	Measured Parameter	Regression equation	R^2	SEE
Male	Humerus	Height = (2.589 x HML) + 78.58	0.658	3.9
Female	Humerus	Height = (2.585 x HML) + 72.01	0.743	2.22

Table 3 shows regression equation formulae for estimation of stature (in cm) from the radiological humerus maximum length (HML) The SEE tends to predict the deviation of estimated stature from actual stature. It is 3.9 cm in males and 2.22cm in females. A low value of SEE is indicative of the greater reliability of the prediction. Regression equation for humerus height = (2.589×HML) + 78.58 for males and height =(2.585× HML) + 72.01 for females and correlation coefficient R^2 0.6.58 in males and 0.743 in females.

Table 4. Percentiles of distribution of statures, humerus length with coefficient points at 25th and 75th percentiles

Variables	Male Stature	Male Humerus (HML)	Females Stature	Females Humerus (HML)
25th	162.53	32.425	151.89	30.9
75th	169.20	35	155.76	32.4

The Table also displays the corresponding categorization of maximal length of humerus in males and females with the same percentile cut off points (25th and 75th). According to proposed divisions for short, medium and tall, this would mean that individuals stature <162.53 cm would be classified as short, 162.53 to 169.20 cm as medium, and >169.20 cm as tall in males, for females, and individuals <151.79 cm would be described as short, between 151.79 to 155.76 cm as medium and >155.76 cm as tall. Among males, HML <32.42 cm were categorized as short, 32.42 to 35 cm as medium and >35 cm as long groups. As regards females, the humerus <30.9 cm were categorized as short, 30.9 to 32.4 cm as medium, and >32.4 cm as long groups.

Table 5. Comparison between the mean of actual & estimated stature (in cm) using the obtained univariate formulae

Sex		Actual Stature (cm)	Estimated stature using HML formula (cm)
Males(n = 71)	Mean ± SD	165.97 + 6.72	165.94 + 5.45
	Mean difference $\pm$ SD		0.027 + 3.93
	Paired t		0.713
	P		0.477 NS
Female (n=37)	Mean ± SD	153.59 + 5.79	153.76 + 3.83
	Mean difference $\pm$ SD		0.025 + 2.25
	Paired t		0.721
	P		0.473 NS

NS : Not significant

Table 5 shows the difference between the actual and estimated stature when the regression formulae were applied for the tested sample and there was no statistical significant difference between them.

Table 6. Comparison between the mean of actual and estimated stature (in cm) using obtained univariate formula in difference bone length categories

	Bone length category	Equation variant	Actual stature (Mean ± SD)	Estimated stature mean ± SD	Difference mean ± SD	paired f p value
Male	Short (N = 18)	Humerus	159.22 ± 4.052	158.98 ± 2.76	0.239 ± 3.243	0.891 0.379 NS
	Medium (N = 35)		166.06 + 4.13	166.31 + 1.997	-0.253 ± 3.394	0.98 0.331 NS
	Long (N = 17)		172.941 + 6.20	172.56 + 3.226	0.380 ± 5.531	0.871 0.39 NS
Female	Short (N = 10)	Humerus	148.5 + 2.635	149.353 + 2.772	-0.853 ± 2.37	1.535 0.142 NS
	Medium (N = 15)		153.467 + 0.713	154.092 + 1.843	-0.626 ± 1.965	1.609 0.119 NS
	Long (N = 12)		158.583 + 2.746	157.013 + 2.855	1.570 ± 1.796	3.059 0.005 *

* Significance at $p \leq 0.05$

Table 6 displays a comparison of actual stature and stature estimated from the obtained regression formula when applied to the 60 subjects after categorization into three groups according to their bone length (short, medium and long). The table also shows that the mean difference between actual and estimated stature, upon application of the formula on short group males was 0.239 ± 3.243 cm and 0.853 ± 2.37 cm in females, which was insignificant by applying paired test (p>0.005). Medium group was 0.253 ± 3.39 cm in males and 0.626 ± 1.96 cm in females, which was insignificant by applying paired test (p>0.005). Long group was 0.38 ± 5.53 cm in males, which was insignificant by applying paired test.

DISCUSSION

Taking in to account the various published data from literature and comparing it with the present series, a few interesting facts came in the lime light. The studied group consists of 107 (70 males and 37 females) Indian adults from north Karnataka, Bijapur aged from 21 years to 60 years with mean ages were 35.60±11.16 for males and 36.65±10.5 females referred to diagnostic and interventional radiological department from faculty of medicine, general surgery, at Al-Ameen medical college and hospital. In the current study revealed that age difference between sexes are statistically insignificant which is in agreement of previous observation made by A Sheta *et al* .[21] In the current study the stature of the studied group ranged from 150 to 188 cm mean (165.97±6.72) for males and 144 to 164 cm mean (153.49 ± 5.79) and there was statistically significant difference between stature of the males and females. This observation is similar observation made by A Sheta *et al*.[21] The current study revealed that males presented with higher value of height than females. The average height of adult male within a population is significantly higher than that of adult female which is in agreement with Williams *et al*, Ebite *et al* , Ilayperuma *et al*.[22,23,24] There was distinct sexual dimorphism in the humerus length in our study group where it was significantly longer in males than in females, a result that reinforces the previous observation and It also revealed that humerus as useful bone for metric determination of sex.

Therefore determination of sex is necessary before estimation of the stature.[21] The present results showed that the stature is correlated with maximal humerus length which is in agreement with Choi *et al* . Studies that dealt with the reconstruction of height and also demonstrated the correlations of humerus length with the body height which is in agreement with A Sheta *et al*.[9,21] The reliability of stature estimation from bone using regression equations is revealed by standard error of estimate. Petrovecki *et al*. showed that correlation between the stature and long bone length was the best for the upper limb bone, humerus in female in Croatian population.[27] In contrast to this findings Choi *et al*. and Munoz *et al*. who concluded that the bones of the lower limb are more correlated and more accurate predictor of stature compared to the bones of the upper limb.[9,28] Studies on secular change and allometry have demonstrated differential limb proportions between sexes and among population the need for gender specific formulae is proved as the rate of skeletal maturity in males and females tend to vary during the course of development. [29,30,22]

Our regression equation of humerus:

Male Height = (2.589 x HML) + 78.58
Female Height = (2.585 x HML) + 72.01

The result of the present study can be compared with similar available studies on different populations regarding to SEE of stature estimation regression equations. In the present study the standard error of estimates ranged from 2.22 to 3.9cm. The standard error of estimates recorded in the present study was lower than that obtained in the study of A Sheta *et al*. They obtained SEE from 4.62 to 4.98cm when they used humerus length for formulation of equation for stature estimation among adult Egyptians. A low value of SEE indicative of the greater reliability of the prediction.[21] The results from other studies using another bones of the body include standard errors of estimates of 5.89 to 7.28cm for the skull, 5.30 to 5.49cm for the vertebral column ,6.51 to8.24cm for tibia, 3.91 to 3.92cm for femur, 5.10 to 8.14cm for metacarpal and 4.13 to 6.07cm for the talus and calcaneus.[21] The present work percentile with cut-off 25 -75 was used to categorize the stature and studied bone lengths (FML & HML) into (short, medium and tall or long) categories. The lower 25% of the distribution are regarded as short, those in the upper 25% as tall or long and the remaining: middle 50% was classified as medium. The obtained equations were validated on a group of Indian adults (North Karnataka Bijapur city) with the same age of the studied sample. The obtained equations revealed reliable stature estimation where the difference between actual and estimated stature was statistically insignificant.

In our study when the obtained formulae was revalidated again on the same group after its categorization based on the bone length (short, medium and long), since the actual height of victims is generally unknown in forensic cases; It has been demonstrated accurate stature estimates with insignificant difference between actual and estimated stature among the short and medium category in both sex and in long category in males. Along with this on the other hand it showed inaccurate estimate with significant difference between actual and estimated stature for individuals at long category in females which may be a problem in a forensic examination. Yet this difference was not significantly apparent when the formula was applied for individuals without categorization. While stature estimation from radiological determination of humerus and femur lengths among Egyptian adults by A Sheta *et al*. Revealed that accurate stature estimates with insignificant difference between actual and estimated stature among the medium category only and inaccurate estimate with significant difference between actual and estimated stature for individuals in height extremes (short and tall).[21] In conclusion, humerus is good predictor for estimation of stature among Indian adults and its equation revealed higher accuracy in the short and medium category in both sex and in long category in males. However our sample size is small so large scale study is required to build up formulation based on stature specific group in Indian adults from North Karnataka.

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