Estimation of length of the ulna from the bony markers of the proximal end in South Indian population

Suja Prasannakumar[1], K.G. Selvaraj[2], Suganthy Rabi[1], Sunil J. Holla[1]

1- Department of Anatomy.
2- Department of Biostatistics, Christian Medical College, Vellore, India.

SUMMARY

The determination of sex, race and the estimation of stature from fragment remains of bones plays an important role in identifying unknown bodies. The length of long bones such as the humerus, femur, radius, have been estimated using several bony markers and hence stature. The aim of the present study was to measure bony markers at the proximal end of ulna and to correlate these markers with length for formulating equations to estimate the length of the ulna in the South Indian population. A total of 110 ulnae (right-84, left-26) were measured. Fourteen measurements were made at the proximal end of ulna using vernier calipers and the data were analyzed statistically. The data revealed a non-significant bilateral variation in the fragmentary measures of the ulna. Regression equations were formulated for the estimation of the length of the ulna from its proximal fragments. For ulnae on the right side, the distance between the tip of the olecranon process posteriorly and the anterior-most point on the radial notch distally, and for ulnae on the left side, the distance between the tip of coronoid process of ulna to the point on the posterior aspect of the ulna at the same level and the distance between the anterior and posterior ends of the radial notch were the best markers for predicting ulnar length. The length of the ulna could be used to estimate the stature of an individual from regression equations, conversion tables and multiplying factors that are already available in forensic anthropometry. Therefore, the estimation of the length of the ulna using the bony markers at the proximal end has potential application in physical anthropology and forensic identification of an individual.

Key words: Ulna – Proximal end – Bony markers – Length – Stature

INTRODUCTION

Interest in reconstructing the stature of skeletal remains dates back to the early 1800s and human limb bones have been used for the estimation of stature in the field of forensic medicine. Stature has been reconstructed, using regression formulae for long bones (Trotter and Gleser, 1977; Genoves, 1967). Bony markers are useful in physical and forensic anthropology. If the body of an individual has been dismembered or if the skeleton is disintegrated, bony markers can be used to estimate the length of a bone (Singh et al., 1974).

Submitted: June 28, 2010
Accepted: July 27, 2010

Correspondence to:
Dr. Suganthy Rabi. Department of Anatomy, Christian Medical College, Vellore 632 002, India. Phone: (Res) 91-0416-2260545/ 2284387; (Off): 2284245;
Fax: 0091-0416-2262268. E-mail: suganthyrabi@cmcvellore.ac.in

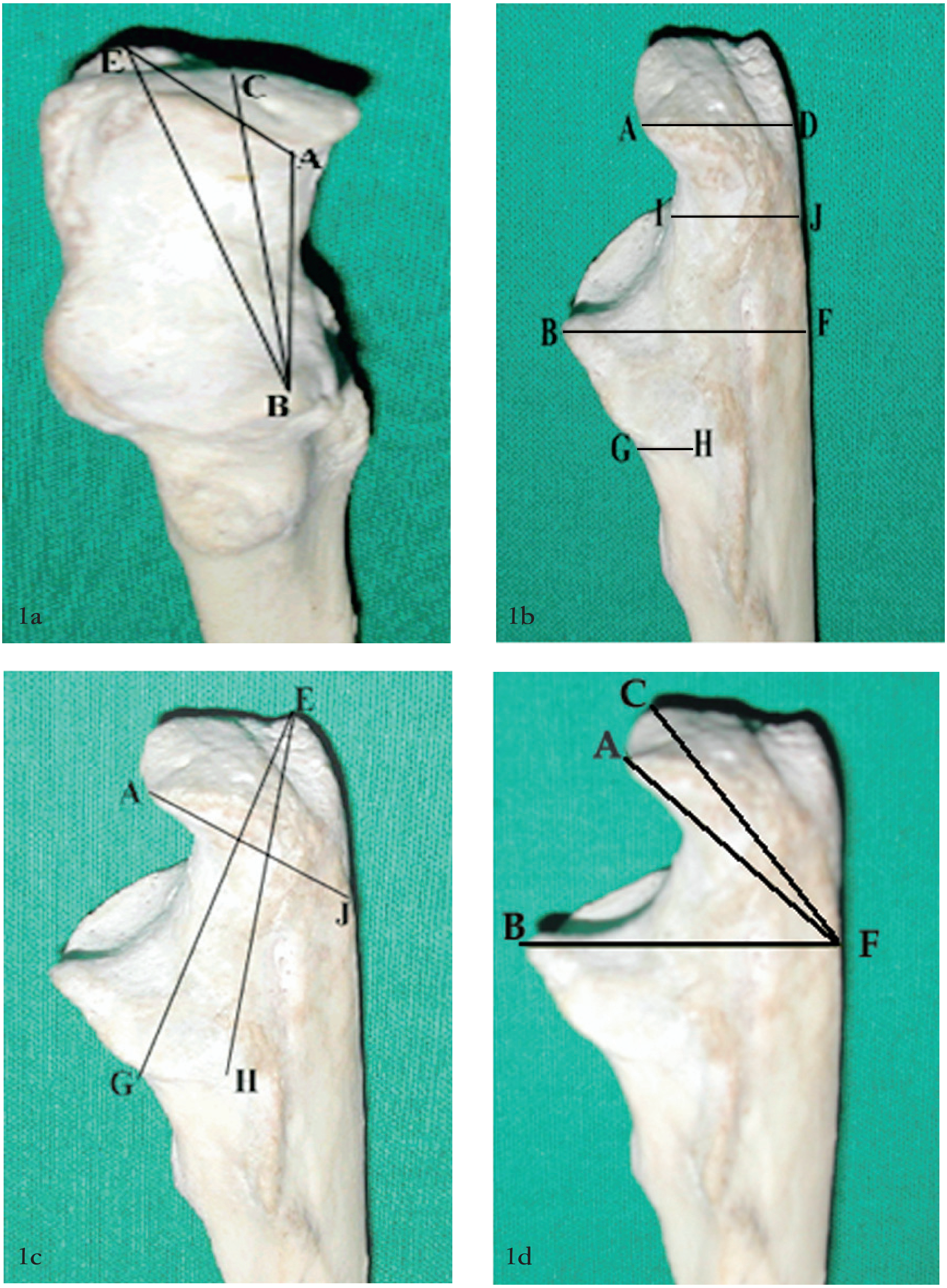

Fig. 1. Upper end of the ulna showing the different points taken for measurement. **1a**: Upper end of the ulna (anterior view). **1b, 1c, 1d**: Upper end of the ulna (posterolateral view). A - anterior-most point on the trochlear notch superiorly; B - anterior-most point on the trochlear notch inferiorly; C - superior-most point on the olecranon process; D - point on the posterior aspect of ulna where the perpendicular to the long axis of the ulna passes through point A; E - tip of the olecranon process posteriorly; F - point on the posterior aspect of the ulna where the perpendicular to the long axis of the ulna passes through point B; G - anterior end of the radial notch; H - posterior end of the radial notch; I - posterior most point of the trochlear notch; J - point on the posterior aspect of ulna where the perpendicular to the long axis of the ulna passes through the posterior-most point of the trochlear notch.

The intertubercular sulcus of the humerus was used as an indicator of handedness and humeral length (Selvaraj et al., 1988). The bony markers of the proximal femur (Prasad et al., 1996), the distal end of the radius (Holla et al., 1996) and from different segments of the ulna (Shende and Parekh, 2009) were used for reconstructing the length of the femur, radius and ulna respectively. The aim of this study was to note the bony markers at the proximal end of the ulna, in order to formulate regression equations to estimate the length of the ulna in the South Indian population and to compare the estimated length of the ulna with the actual length in a restricted sample.

Materials and Methods

1. *Estimation of ulna length from the bony markers at the proximal end*

One hundred and ten dry ulnae (right-63, left-47) from a South Indian population were used for this study. The bones were not catalogued and hence the sex and stature of the individual were not known. Bones having any fracture, variations or pathology were excluded.

Bony markers at the coronoid process, olecranon process, trochlear notch and radial notch of the ulna at the proximal end of the ulna were studied. To measure certain dimensions on the posterior aspect of the ulna, the ulna was placed on a glass sheet (X) with a thickness 0.49 cm. Fourteen dimensions were measured from the proximal end of the ulnas, using techniques recommended by Singh and Bhasin (1989):

1. Measurement of the distance between the anterior-most point on the trochlear notch superiorly and inferiorly (AB) (Fig. 1a).
2. Measurement of the distance between the superior-most point on the olecranon and anterior-most point on the coronoid process of the ulna in the trochlear notch (CB) (Fig. 1a).
3. Measurement of the difference between CB and AB (AC).
4. Measurement of the distance between the tip of the olecranon process posteriorly to the anterior-most point on the trochlear notch inferiorly (EB) (Fig. 1a).

Measurement of the distance between the anterior-most point on the trochlear notch superiorly to the tip of the olecranon process posteriorly (AE) (Fig. 1a).

Measurement of the distance along the perpendicular to the long axis of the ulna from the anterior-most point on the olecranon process to a point on the posterior aspect of the ulna + thickness of the glass (AD+X) (Fig. 1b).

7. Measurement of the distance along the perpendicular to the long axis of the ulna from the tip of coronoid process of ulna to a point on the posterior aspect of the ulna+ thickness of the glass (BF+X) (Fig. 1b).
8. Measurement of the distance between the anterior and posterior ends of the radial notch (GH) (Fig. 1b).
9. Measurement of the distance along the perpendicular to the long axis of the ulna from the posterior-most point on the trochlear notch to a point on posterior aspect of the ulna + thickness of the glass (IJ+X) (Fig. 1b).
10. Measurement of the distance between the anterior-most point on the trochlear notch superiorly to a point on the posterior aspect of the ulna where the perpendicular to the long axis of the ulna passes through the anterior-most point on the trochlear notch inferiorly (AF) (Fig. 1b).
11. Measurement of the distance between the tip of the olecranon process posteriorly and the anterior- most point on the radial notch distally (EG) (Fig. 1c).
12. Measurement of the distance between the tip of the olecranon process posteriorly to the posterior-most point on the radial notch distally (EH) (Fig. 1c).
13. Measurement of the distance between the anterior-most point on the trochlear notch superiorly to a point in the posterior aspect of the ulna where the perpendicular to the long axis of the ulna passes through the posterior-most point of the trochlear notch (AJ) (Fig. 1c).
14. Measurement of the distance between superior-most point on the olecranon process to a point on the posterior aspect of the ulna where the perpendicular to the long axis of the ulna passes through on the coronoid process (CF) (Fig. 1d).
15. Measurement of the length of the ulna (L).

Statistical analysis

Between-group comparisons (right and left) were performed for all the bony markers, using Student's independent t- test. Pearson correlation coefficients were done to assess the relationship between the markers and length. Regression analysis was carried out to find the markers that were related to length and for estimating length using equations. Based on the regression analysis, regression equations were derived to construct the length of the ulna from the significant bony markers. Multivariate regression equations were derived after excluding highly correlated markers using stepwise methods. Analyses were carried out using SPSS version 11.5.

2. *Comparison of the estimated length of the ulna with the actual length in a restricted sample*

After formulating the equations, a restricted sample of five ulna bones that were not used to derive the formula were used to check the accuracy of the equations. The length of the ulna was estimated using the multiple regression equations derived from bony markers. This was compared with the actual length of the ulna and the difference was noted.

Results

1. *Estimation of ulna length from the bony markers at the proximal end*

Means, standard deviations and standard errors were determined for the measured dimensions of the markers and of the maximum length of the ulna. Student's independent t-test was applied and no significant difference was observed in the means between the left and right ulnae (Table 1).

The correlation coefficient between the maximum length of the ulna and each of the dimensions measured was determined. The length of the ulna (y) was regressed on each of

Table 1. Independent t-test of the means of bony markers (Right=63, Left=47)

Marker	Right			Left			P value
	Mean	SD	SE	Mean	SD	SE	
AB	2.08	0.23	0.29	2.10	0.22	0.32	0.63
CB	2.9	0.31	0.04	2.9	0.31	0.04	0.67
GH	1.38	0.17	0.92	1.37	0.22	0.03	0.68
EG	3.8	0.42	0.05	3.63	0.59	0.08	0.06
EH	3.61	0.58	0.07	3.7	0.34	0.05	0.28
CF	2.90	0.35	0.04	3.01	0.37	0.05	0.13
EB	3.38	3.33	0.05	0.39	0.43	0.06	0.57
AF	2.86	0.44	0.05	2.84	0.45	0.06	0.09
EA	2.10	0.32	0.04	2.08	0.25	0.03	0.70
AJ	2.47	0.30	0.38	2.41	0.25	0.36	0.29
AD	2.32	0.31	0.04	2.26	0.30	0.05	0.26
BF	3.00	0.33	0.04	3.09	0.35	0.05	0.18
IJ	1.69	1.77	0.02	1.61	2.0	0.03	0.07
Length	25.40	2.02	0.25	25.59	1.73	0.26	0.29

SD- standard deviation; SE- standard error.

Table 2. Univariate analysis of bony markers of ulnae of the right, left and both sides. Here the length of the ulna (dependent variable-y) has been correlated with the bony markers (independent variables). Right side - Number= 63; Left side – Number= 47.

No	Marker	Right				Left				Both			
		(a)	(b)	SE	P value	(a)	(b)	SE	P value	(a)	(b)	SE	P value
1	AB	19.069	3.041	1.052	0.005*	19.693	2.806	1.079	0.013*	19.297	2.958	0.753	0.001*
2	CB	14.496	3.710	0.697	0.006*	17.141	2.852	0.714	0.001*	15.009	3.347	0.584	0.048*
3	AC (CB-AB)	21.799	4.204	1.102	0.001*	24.148	1.648	0.865	0.064	23.145	2.726	0.352	0.001*
4	GH	17.742	5.532	1.354	0.001*	20.749	3.542	1.005	0.001*	19.466	4.369	0.834	0.001*
5	EH	20.029	1.487	0.485	0.001*	14.787	2.908	0.604	0.001*	18.959	1.784	0.325	0.001*
6	CF	17.334	2.778	0.658	0.001*	19.502	2.026	0.620	0.002*	18.358	2.417	0.450	0.001*
7	EB	19.539	1.733	0.625	0.007*	22.394	0.960	0.578	0.102	20.980	1.346	0.427	0.002*
8	EG	13.025	3.244	0.447	0.000*	23.879	0.473	0.428	0.275	19.813	1.517	0.327	0.001*
9	AF	21.339	1.422	0.557	0.013*	23.403	0.772	0.565	0.179	22.241	1.138	0.398	0.005*
10	EA	19.608	2.753	0.713	0.001*	18.123	3.588	0.875	0.001*	19.213	2.993	0.548	0.001*
11	AJ	19.168	2.527	0.786	0.001*	19.514	2.529	0.960	0.012*	19.476	2.463	0.600	0.001*
12	AD	17.452	3.421	0.711	0.001*	19.929	2.513	0.744	0.002*	18.68	2.966	0.515	0.001*
13	BF	17.729	2.554	0.658	0.001*	14.596	3.558	0.636	0.001*	16.634	2.91	0.463	0.001*
14	IJ	15.092	6.068	1.388	0.001*	21.001	2.591	0.882	0.005*	19.059	3.712	0.765	0.001*

a - constant; b - regression coefficient; SE - standard error; * denotes $P<0.05$ (significant).

Table 3. Simple Regression Equations of right, left and both, relating length with the bone markers.

Right	Left	Both
Length=19.069+(3.041 AB)	Length= 19.693+(2.806AB)	Length=19.297+(2.958AB)
Length=14.496+(3.710 CB)	Length= 17.141+(2.852CB)	Length= 15.009+(3.347CB)
Length=21.799+(4.204 AC)	Length= 20.749+(3.542GH)	Length=23.145+(0.352AC)
Length=17.742+(5.532 GH)	Length=19.502+(2.026CF)	Length=19.466+(0.834GH)
Length=13.025+(3.244EG)	Length=18.123+3.588EA)	Length=18.959+(1.784FH)
Length= 17.334+(2.778 CF)	Length=19.514+(2.529AJ)	Length=18.358+(2.417CF)
Length=19.539+(1.733EB)	Length=19.929+(2.513AD)	Length=20.980+(1.346EB)
Length=21.339+(1.422AF)	Length=14.596+(3.558BF)	Length=19.813+(1.517EG)
Length=19.608+(2.753EA)	Length=21.001+(2.591IJ)	Length=22.241+(1.138AF)
Length=19.168+(2.527AJ)		Length=19.213+(2.993EA)
Length=17.452+(2.554BF)		Length=19.47+(2.463AJ)
Length=15.095+(6.068IJ)		Length=18.68+(2.91AD)
Length=17.452+(3.421AD)		Length=17.729+(2.55BF)
Length=20.029+(1.487EH)		Length=16.634+(3.712IJ)

the dimensions (x) and simple regression models at y = a + bX were derived, where 'a' is a constant (baseline) and 'b' is the regression coefficient. Table 2 shows the dimensions and their relationship with the length of the ulna. For the ulnae of the right side, all the markers showed a significant relationship with the length of the ulna ($p<0.05$). For the ulnae of the left side, the dimensions CB, EH, EA, AJ, AD, BF, IJ, AB, GH, and CF, showed a significant correlation with the length of the ulna ($p<0.05$). For the ulnae of both side, all the markers showed a significant correlation with the length of the ulna ($p<0.05$).

Using the regression analysis, simple regression equations were derived to estimate the length of the ulna from the dimensions measured (Table 3). After excluding the highly correlated bony markers, multiple linear regression equations were constructed using the step-wise method. For ulnae of the right side, EG was the best marker to estimate ulna length by multivariate analysis. For ulnae of the left side, BF and GH were the best markers for predicting ulna length. For ulnae of both sides, CB, BF, GH, EH, and AD were the best markers to predict the length of the ulna (Table 4).

Multivariate equations

Right side: Length=13.025 + (3.244EG)
Left side: Length=12.821 + (3.08BF) + (2.376GH)
Both sides: Length=10.668+(1.171CB) +(1.325BF)+(1.614GH)+ (0.707EH)+(1.099AD)

Table 4. Equation for finding the length of ulnae of both sides from bony markers by step-wise analysis.

	Model	Standard Error	P Value	N
CONSTANT	10.668	1.553	0.000	110
CB	1.171	0.584	0.048	110
BF	1.325	0.480	0.007	110
GH	1.614	0.792	0.044	110
EH	0.707	0.313	0.026	110
AD	1.099	0.533	0.042	110

2. *Comparison of the estimated length of the ulna with the actual length on a restricted sample*

The accuracy of the multivariate equations of bone analysis was found to be + 0.6 to - 1.5cm for the ulnae of both sides; +1.4 to - 2.1cm for ulnae of the right side and +0.5 to +1.5cm for ulnae of the left side (Table 5).

Table 5. Comparison of estimated length of the ulna with actual length (Both sides).

S.No.	GH	AD	EH	CB	BF	Calculated Length	Actual Length	Difference
1	1.25	2.4	3.96	3.05	3.6	26.47	25.5	0.97
2	1.29	2.4	3.6	2.95	3.15	25.56	26.6	-1.04
3	1.3	2.24	3.9	3.2	3.4	26.24	25.6	0.64
4	1.35	2.1	3.85	2.51	3.14	24.98	26.4	-1.42
5	1.4	2.45	3.65	3	3.2	25.95	27.5	-1.55

Discussion

Estimation of stature or sex from the long bones plays an important role in the forensic identification of bodies and skeletal remains. Forensic anthropologists are often confronted only with fragmentary remains. In order to estimate stature from long-bone fragments, first the length of the long bone should be estimated. This is then employed in statural formulae. The length of long bones has been estimated from bony markers. The lengths of the radius (Holla et al., 1996; Vettivel et al., 1999), humerus (Selvaraj et al., 1998), and femur (Prasad et al., 1996) has been estimated using bony markers for application in fragmentary bony remains. Mysorekar (1982) studied 351 human ulnae and derived stature equations (simple and multiple regressions) separately for males and females for the estimation of the total length of the ulna from the upper and lower segments. Badkur and Nath (1990) studied three markers on the upper end of the ulna, the height of the radial facet, the height of the ulnar tuberosity and the breadth of the olecranon in an Indian population. In the present study, fourteen dimensions were considered and the work addressed the estimation of the length of the ulna from bony markers on the proximal end of ulnae from people of undetermined sex in South Indian population. In this study, no significant difference was observed between the means of the markers on right and left bones, which is in accordance with a previous study (Badkur and Nath, 1990). All fourteen dimensions of the ulna on the right side and ten dimensions on the left side had a statistically significant correlation with the length of the ulna (Table 2). From these dimensions, univariate regression equations can be derived for the estimation of the length of the ulna.

Simple and multiple regression equations are derived for the estimation of the length of the ulna for right, left, and both sides from bony markers. For ulnae on the right side, distance between the tip of the olecranon process posteriorly and the anterior-most point on the radial notch distally, EG was the best marker to determine the ulna length using multivariate analysis. For ulnae on the left side, the distance along the perpendicular to the long axis of the ulna from the tip of coronoid process of the ulna to a point on the posterior aspect of the ulna (BF) and the distance between the anterior and posterior ends of the radial notch (GH) are the best markers for predicting the length of the ulna. For ulnae on both sides, the distance between the superior-most point on the olecranon and anterior-most point on the coronoid process of the ulna in the trochlear notch (CB), the distance along the perpendicular to the long axis of the ulna from the tip of coronoid process of the ulna to a point on the posterior aspect of the ulna (BF) and the distance between the anterior and posterior ends of the radial notch (GH), the distance between the tip of the olecranon process posteriorly to the posterior-most point on the radial notch distally (EH) and the distance along the perpendicular to the long axis of the ulna from the anterior-most point on the olecranon process to a point on the posterior aspect of the ulna (AD) are the best markers for predicting the length of the ulna.

The length of the ulna can be used to estimate the stature of an individual from the regression equations, conversion tables and multiplying factors that are used in forensic anthropometry. Though various factors such as age, sex and race have to be borne in mind when estimating the stature of an individual, the statistically highly significant formulae provide a means for establishing the stature of an individual with adequate accuracy.

In conclusion, the maximum length of ulna can be estimated even from a single available fragment of proximal ulna using values of regression co-efficient and intercept for a known measurement of a significant marker. The regression values derived from the modern population of the southern part of India to estimate ulnar length is an intermediate step in predicting the stature of an individual in the South Indian population. Such an estimate of ulnar length and stature has potential application in physical and forensic anthropology.

Acknowledgements

The authors thank the Fluid Research Committee of Christian Medical College for funding this project.

References

Badkur P, Nath S (1990). Use of regression analysis in reconstruction of maximum bone length and living stature from fragmentary measures of the Ulna. *Forensic Sci Int,* 45: 15-25.

Genoves S (1967). Proportionality of the long bones and their relation to stature among Mesoamericans. *Am J Phy Anthropol,* 26: 67-77.

Holla SJ, Vettivel S, Chandi G (1996). Bony markers at the distal end of the radius for estimating handedness and radial length. *Ann Anat,* 178: 191-195.

Krogman WM, Iscan MY (1986). The Human Skeleton in Forensic Medicine. In: Charles C. Thomas (ed), Springfield, pp 303-349.

Mysorekar VR, Nandedkar AN, Sarma TCSR (1982). Estimation of stature from parts of humerus and radius. *Med Sci Law,* 22: 178-180.

Prasad R, Vettivel S, Jeyaseelan L, Isaac B, Chandi G (1996). Reconstruction of femur length from markers of its proximal end. *Clin Anat*, 9: 28-33.

Selvaraj KG, Vettivel S, Indrasingh I, Chandi G (1988). Handedness identification from intertubercular sulcus of the humerus by discriminant function analysis. *Forensic Sci Int,* 98: 101-108.

Singh IP, Bhasin MK (1989). A laboratory manual on biological Anthropology- Anthropometry. Kamalaraj Enterprises, Delhi, pp 247.

Singh S, Singh G, Singh SP (1974). Identification of sex from the ulna. *Indian J Med Res*, 62: 731-735.

Trotter M, Gleser GC (1977). Corrigenda: "Estimation of stature from long limb bones of American whites and Negroes. *Am J Phy Anthropol,* 47: 355-356.

Vettivel S, Prasad R, Selvaraj KG, Chandi G (1999). Estimation of length and gender of radius from its bony markers. *Indian Anthrop Soc*, 34: 81-92.