ESTIMATION OF STATURE

FROM THE BONY MARKERS OF

PROXIMAL END OF ULNA

Dissertation submitted in partial fulfillment of the

Degree of Master of Surgery (Anatomy)

of

The Tamil Nadu Dr. M. G. R. Medical University,

Chennai

by

Dr. Suja R.S

CERTIFICATION

This is to certify that the dissertation Titled "Estimation of stature from the bony markers of proximal end of ulna" *is based on the results of the work carried out by*

Dr. SUJA R.S.

for the degree of Master of Surgery (Anatomy) under my supervision. The work reported in this dissertation has not been submitted to any other university for the award of a degree.

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CONTENTS

ACKNOWLEDGEMENTS

I would like to thank the following people:

Dr. Sunil J. Holla, Professor of the Department of Anatomy, for his expert supervision, guidance and constant encouragement.

Dr. Rachel Koshi, the Head of the Department of Anatomy, for her valuable suggestions and help.

Dr. Rekha Cherian, the Head of the Department of Radiology and Mr. Edwin Simon, Superintendent of the Radiology Department, for their help with my radiological studies.

Dr. K.G. Selvaraj and Ms.Nithya, Department of Biostatistics, for their guidance in statistical analysis.

Dr. J. Suganthy, Senior Lecturer and Ms. Sakunthala Ambikaipakan, Ph.D. student, of the Department of Anatomy, for their encouragement and support.

Dr. Tripti, P.G. student, Department of Anatomy for her help in preparing the references.

Dr. Aswathy, Demonstrator, Department of Anatomy, for her patience in compiling this work.

Mr. V. Gopinath, Secretary, Department of Anatomy, for his timely help.

Teaching and non-teaching staff of Department of Anatomy, for their cooperation and help as and when it was necessary.

The Fluid Research Grant Committee, for funding this work.

Above all, I am extremely thankful to the Almighty for His help in each step of this study.

TITLE OF THE ABSTRACT : ESTIMATION OF STATURE FROM THE BONY MARKERS OF PROXIMAL END OF ULNA

NAME OF THE CANDIDATE : DR. SUJA. R. S

DEGREE AND SUBJECT : M.S. ANATOMY

NAME OF THE GUIDE : DR. SUNIL J HOLLA

OBJECTIVES:

To measure bony markers at the proximal end of the ulna and to correlate these markers with its length for formulating equations to estimate length of the ulna and stature in south Indian population.

METHODS

The present study deals with the computation of linear regression formulae for reconstruction of ulnar length and stature from bony fragments of upper end of the ulna. A total of 110 ulnae (right-63, left-47) were measured for this purpose. Fourteen markers at the proximal ends of 110 dry ulnae were measured with vernier calipers. Length of the ulnae was measured with osteometric board.

Forty-five (45) radiographs of forearm showing both ends of ulnae of thirty (30) individuals were taken. Four markers from the proximal end of radiographs and the length of the ulnae were measured with a measuring scale. Stature of these individuals was measured with measuring rod.

Statistical method

Independent t-test, Regression analysis, Pearson correlation test, and stepwise method were used for this study. All analyses were carried out using SPSS version 11.5.

RESULT

The data revealed non-significant bilateral variation in the measurements of the ulna. Regression equations were formulated for the estimation of length of the ulna from bony markers. Multiple linear regression equations were constructed using the stepwise method. It was shown that a single dimension for right side, the distance between the tip of the olecranon process posteriorly and the anterior-most point on the radial notch can estimate the stature of an unknown person with great accuracy. Regression equation for finding out height from the length of the ulna was also derived from radiographs of 30 individuals.

INTRODUCTION

Anthropometry is the study of the measurements of the human body in terms of the dimensions of bone, muscle and adipose tissue. Anthropometric techniques commonly used by anthropologists and adopted by medical scientists have been employed to estimate body size for over hundred years. Interest in reconstructing stature from skeletal remains dates back to the early 1800s. Human limb bones have been used for the estimation of stature in the field of forensic medicine since the 19th century. Stature was reconstructed, using the regression formulae for long bones, described by Trotter and Gleser, 1952; Stevenson, 1929; Breitinger, 1938;Telkka, 1950; Dupertuis and Hadden, 1951; Keen, 1953; Genoves, 1967; Trotter and Gleser, 1977. Populations, on which these equations were based, included European-Caucasian, American-Caucasian, African-American, African, Meso-American and a heterogeneous group of Mongolians. The determination of sex and the estimation of stature from bones play an important role in identifying bodies and skeletal remains. Useful information for the estimation of stature can be obtained from sources besides the length of the long bones of the limbs. Other bones, such as metacarpal bones (Musgrave and Harneja, 1978), fragmented limb bones (Steele et al., 1969); clavicle (Singh and Sohal, 1952; Jit and Singh, 1956) and scapula (Olivier and Pineau, 1957) were investigated for the same purpose. 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 (Steele and

McKern, 1969; Holla et al., 1996; Steele, 1970; Singh et al., 1974). Measurements of the Intertubercular sulcus of the humerus were used as an indicator of handedness and humeral length (Vettivel et al., 1995). Bony markers of proximal femur such as neck-shaft angle, neck length, intertrochanteric apical axis length and vertical diameter of the head were used for reconstructing the length of the femur (Prasad et al., 1996). It was noted that none of these workers reported the use of fragmentary remains of the ulna for the estimation of stature. This may be due to the fact that the length of the ulna contributes a less accurate estimation of stature than the length of other long bones. However, in the absence of adequate remains it is worthwhile to have such an estimate rather than totally ignoring the burnt or broken fragments of the ulna when an estimate is required.

Normal Anatomy of the ulna

The ulna (Fig.1) is medial to the radius in the supinated forearm. Its proximal end forms a massive hook, which is concave forwards. The lateral border of the shaft is the sharp interosseous border. The bone diminishes progressively from its proximal mass throughout almost its whole length, but at its distal end expands into a small rounded head and styloid process.

<u>Proximal end</u>

The proximal end has large olecranon and coronoid processes and trochlear and radial notches, which articulate with the humerus and radius respectively. The olecranon process is more proximal and is bent forwards at its summit like a beak, which enters the humeral olecranon fossa in extension. Its posterior surface (Fig.2) is smooth, triangular and subcutaneous. In extension the tip of the olecranon process can be felt near a line joining the humeral epicondyles, but in flexion it descends, so that the three osseous points form an isosceles triangle. The anterior part of the olecranon process (Fig.3) has an articular surface, which forms the proximal area of the trochlear notch. It is slightly constricted where it joins the shaft and is the narrowest part of the proximal ulna. The coronoid process projects anteriorly distal to the olecranon. Its proximal aspect forms the distal part of the trochlear notch. On the lateral surface (Fig.4), distal to the trochlear notch, there is a shallow, smooth, oval radial notch that articulates with the radial head. Distal to the radial notch the surface is hollow to accomodate the radial tuberosity during pronation and supination. The anterior surface (Fig.3) of the coronoid process is triangular. Its distal part is the tuberosity of the ulna. Its medial border (Fig.5) is sharp and bears a small tubercle proximally.

The trochlear notch (Fig.4) articulates with the trochlea of the humerus. It is constricted at the junction of the olecranon and coronoid processes, where a narrow rough nonarticular strip may separate their articular surfaces. A smooth ridge, adapted to the groove on the humeral trochlea, divides the notch into medial and lateral parts. The medial part fits into the trochlear flange. The radial notch, an oval or oblong proximal depression on the lateral aspect of the coronoid process, articulates with the periphery of the radial head, and is separated from the trochlear notch by a smooth ridge.

Shaft

The shaft (Fig.4) is triangular in section in its proximal three-fourths, but distally is almost cylindrical. It has anterior, posterior and medial surfaces and interosseous, posterior and anterior borders.

Distal end

The distal end is slightly expanded and has a head and styloid process (Fig.1). The head is visible in pronation on the postero-medial carpal aspect, and can be gripped when the supinated hand is flexed. Its lateral convex articular surface fits the radial ulnar notch. Its smooth distal surface is separated from the carpus by an articular disc, the apex of which is attached to a rough area between the articular surface and styloid process. The latter, a short, round, postero-lateral projection of the distal end of the ulna, is palpable (most readily in supination), 1 cm proximal to the plane of the radial styloid. A posterior vertical groove is present between the head and styloid process.

Ossification

The ulna ossifies from four main centers, one each in the shaft and in the distal end and two in the olecranon process. Ossification begins in the mid shaft about the eighth fetal week, and extends rapidly. In the fifth (female) and sixth (males) years, centers appear in the distal end, and extend in to the styloid process. The distal olecranon is ossified as an extension from the shaft, and the rest from a thin scale-like proximal epiphysis on its summit. The latter appears in the ninth year in females, and eleventh in males.

The whole proximal epiphysis has joined the shaft by the fourteenth year in females and sixteenth in males. The distal epiphysis unites with the shaft in the seventeenth year in females and in the eighteenth year in males (Johnson and Ellis, 2005).

AIMS OF THE STUDY

1. To measure bony markers at the proximal end of ulna.

2. To study the correlation between the bony markers at the proximal end of ulna and its length.

3. To formulate equations to estimate length of the ulna from bony markers on the ulna in the south Indian population.

4. To compare the estimated length of the ulna with the actual length on a restricted sample.

5. To formulate equations to estimate stature from radiographic markers on the ulna.

REVIEW OF LITERATURE

Estimation of stature or sex from the long bones plays an important role in the forensic identification of bodies and skeletal remains. Telkka (1950) mentioned that the prediction of human stature on the basis of long bones holds a central position in anthropology. Orfila (1831) presented the first tables worked out on the basis of actual bone measurements by means of which the stature could be predicted. Determination of sex from human skeletal remains plays a very important role in establishing the identity of an individual. It has been noted by Krogman and Iscan (1986) that very high prediction accuracy can be reached if a well-preserved entire skeleton is available. This chapter deals with the review of several studies on the use of bones in estimating stature and sex.

ESTIMATION OF STATURE:

Different anthropologists estimated the actual stature of individuals from exhumed bones, using statural formulae. In 1888, Rollet published the earliest formal statural tables in France, using the humerus, radius, ulna, femur, tibia and fibula of 50 male and 50 female cadavers. The bones were measured first in the ”fresh state” and 10 months later in the “dry state“. During this time they had lost 2mm in overall length. In 1892 and 1893, Manouvrier re-assessed Rollet’s data but excluded all subjects over 60 years of age, for he considered that in old age some 3cm of calculated stature has been lost. There were 2 methodological differences between Rollet and Manouvrier that must be noted. Manouvrier determined the average stature of individuals who presented the same length for a given long bone; Rollet determined the average length of a given long bone from individuals with the same stature. In 1899, Pearson using Rollet's data developed regression formulae based on bones from the right side only.

In 1952, Trotter and Gleser published a definitive study on stature calculation for American whites and blacks. Data used were from the dead of World War II and the Terry Collection. All 6 long bones were measured for maximum length, along with bicondylar length of the femur and tibial length between upper and lower articular surfaces. Blacks of both sexes had longer arm and leg bones than whites. They also have longer forearm and leg bones relative to upper arm and thigh. In 1958, Trotter and Gleser re-evaluated the entire problem of statural reconstruction from long bones using the skeletal material from casualties of the Korean War. They mentioned that the relationships of stature to the length of long bones differ sufficiently among the three major races (White, Negro, Mongoloid) to require different regression equations from which to derive the most precise estimates of stature belonging to each of these groups.

In 1961 Allbrook attempted to develop standards for estimation of stature from a British sample using percutaneous tibial and ulnar lengths. Ulnar length was measured from the tip of the olecranon process to the distal margin of the head of the ulna (palpable on the dorsum of the wrist) with the forearm flexed and semi-pronated and the hand in the neutral position. Telkka (1950) stated that if bones are measured fresh, 2mm must be deducted from each bone to get the length of the dry bone.

Estimation of stature from body parts:

Cheng (1998) studied arm span and foot length of 3647 Chinese children and estimated stature with regression equations. Attallah and Marshall (1986) estimated stature from measurements of some limb segments (upper limb, upper arm, forearm, leg, hand and foot). Simple and multiple regression equations were derived for estimation of stature from these segments. Ozaslan et al. (2003) estimated stature from trochanteric height, thigh length, lower leg length, leg length, and foot height, breadth, and length by regression analysis.

Estimation of stature using the whole long bone:

Joshi et al. (1964) studied 50 healthy male medical students in Gujarat in the age group of 18-22 years. In his study length of the ulna and length of the tibia were taken into consideration. He concluded that in determining the total height of an individual, knowledge of both tibia and ulnar lengths was important even though the height can be predicted by a regression equation of height on tibia length or on ulnar length alone.

Athawale (1963) correlated length of radius and ulna with height. Regression formulae were derived for stature based on the different measurements. Humphry (1958) prepared tables (in England) by means of which stature could be calculated.

Nat (1931) estimated stature from long bone length by multiplying it with multiplication factors. He worked on the humerus, radius, ulna, femur, tibia and fibula.

Estimation of stature from bony fragments:

If the body of an individual has been dismembered or if the skeleton is disintegrated, bony markers of the radius can be used to estimate the length (Steele, 1969) or gender (Singh et al., 1974) of that bone.

Holla et al. (1996) studied the measurements of the size of bony markers at the distal end of the radius in 61 left and 64 right dry radii. It was proposed that the greater distance between the dorsal tubercle and styloid process and the greater dorso-palmar diameter of the carpal articular surface opposite to the dorsal tubercle were indicative of right-handedness. The length of the radius was found to correlate significantly with bony markers. Regression equations for the length of the radius were derived. The estimated length of the radius can be used to estimate the stature of an individual by referring to the regression equations, tables and multiplication factors that are available (Nat, 1931; Siddique and Shah, 1944; Telkka, 1950; Dupertuis and Haddon, 1951; Trotter and Gleser, 1952, 1958; Athawale, 1963; Kolte and Bansal, 1974; Patil et al., 1983).

Vettivel et al. (1999) measured maximum length and twenty other bony markers on 68 dry unpaired radii of known gender (34 right and 34 left, 42 male 26 female). They estimated the maximum length from a fragment of radius and the gender from a single radius. Simple regression equations were derived to calculate the estimated length of the radius.

Vettivel et al. (1995) estimated length of the humerus using measurements of the intertubercular sulcus as markers. Prasad et al. (1996) estimated the length of the femur using markers at the proximal end of the femur.

Mysorekar (1982a) studied 277 radii to derive regression formulae for estimation of the total length of the radius from the upper and lower segments. The regression formulae that were derived have a high degree of prediction, and are valuable in establishing the stature of an individual.

Badkur and Nath (1990) studied 288 ulnae belonging to 82 male and 62 female skeletons. Their study indicated that the upper shaft circumference is the best predictor of ulnar length among the fragmentary measures they described and stature can best be reconstructed using the breadth of the olecranon. Koshy et al., (2001), studied 110 calcanei and 70 tali and found that the maximum length of the calcaneum significantly correlated with maximum transverse width of the calcanei, depth of the groove on the sustentaculum tali, length, width and depth of the sulcus calcanei. Maximum length of the talus significantly correlated with maximum transverse width, length and width, length and width of articular surface for the lateral malleolus, length of articular surface for the medial malleolus, vertical and transverse diameters of head and depth of the sulcus tali. Simple regression suggested that maximum length of calcaneum regressed significantly with maximum transverse width, length and depth of the groove on the sustentaculum tali, length, depth of the sulcus calcanei, and maximum length of the talus regressed significantly with maximum transverse width, length and width of the lateral articular surface, length of the medial articular surface, vertical and transverse diameters of the head and depth of the sulcus tali.

Mysorekar (1982b) estimated stature from parts of ulna and tibia. He studied 351 fully ossified human ulnae to derive regression formulae for the estimation of total length of the ulna from the upper and lower segments. The line of separation between segments was the lowest level of the insertion of the brachialis muscle. This study was undertaken to derive regression equations, which would have a high degree of prediction for the estimation of the total length of the ulna. Eventually the stature of the deceased could be estimated from various formulae available for the ulnae. Regression equations were derived to correlate the length of the upper or lower segment of the ulna to the total length of the ulna. It was noted that the correlation between the length of the lower segment to the total length was comparatively much greater than that of the upper segment to the total length of the bone in all the right and left ulnae. Hence it is felt that in all these bones the regression equation for the lower segment should be preferred for prediction purposes. This would give a difference of barely 1-2mm in the estimated total length of the ulna. Mysorekar (1982b) concluded that a regression equation derived by using a longer segment of a bone is preferable to using a smaller segment.

ESTIMATION OF SEX FROM BONE:

Determination of sex from human skeletal remains plays a very important role in establishing the identity of an individual. It is said that very high prediction accuracy can be reached if a well-preserved entire skeleton is available (Krogman and Iscan, 1986; Jit 1979).

Purkait (2001) advocated use of demarking points of ulna (olecranon-coronoid angle, length and width of inferior medial trochlear notch), which helped to identify the sex with 90.6% accuracy. He measured dry adult ulnae (100 male and 60 female). His study revealed that the olecranon-coronoid angle was the single best parameter for sex determination, yielding 85% accuracy.

Badkur and Nath (1990) in their study on 288 ulnae found that sex differences were highly significant at 1% level. Keeping this in view, separate regression equations were formulated for both sexes.

Introna (1993) observed that the highest percentage of correct sex classification of 95% was obtained using the minimum circumference and maximum length of the ulna together. Using four discriminant functions sex was correctly identified in 93.75% of the sample.

Vettivel et al. (1999) measured maximum length and twenty other bony markers using osteometric board, sliding caliper, and goniometer on 68 dry unpaired radii of known gender (34 right and 34 left, 42 male 26 female). Their data was statistically analysed so as to estimate the maximum length from a fragment of radius and the gender from a single radius. Simple regression equations were derived to estimate the length of the radius. Student's unpaired t-test was used to determine which markers showed a significant gender difference. Fisher's discriminant function (multivariate) analysis was done on all the 21 markers to differentiate gender from a single radius and included nine significant markers.

If the body of an individual has been dismembered or if the skeleton is disintegrated, bony markers of the radius can be used to estimate the length (Steele, 1969) or gender (Singh et al., 1974) of that bone. According to Jit (1979) it may not be difficult to predict the gender of an adult when an almost complete skeleton is available.

Purkait (2001) advocated use of demarking points of ulna (olecranon-coronoid angle, length and width of inferior medial trochlear notch), which helped to identify the sex with 90.6% accuracy. He measured dry adult ulnae (100 male and 60 female) of Madhya Pradesh. In his study direct analysis using single and multiple variables revealed the olecranon-coronoid angle as the single best parameter for sex determination yielding 85% accuracy.

Skeleton development is influenced by a number of factors producing differences in skeletal proportions between different geographical areas. Racial differences in mean adult heights and limb bone length between populations have been reported (Trotter, 1958). Length and width of inferior medial articular notch was measured and when a test of significance was applied, it yielded highly significant differences, for sexing the ulna. An advantage of measuring the length and width of inferior medial articular notch for sex determination is that the measurements can be taken on fragmentary bone where only the upper end is available (Purkait, 2001).

MATERIALS AND METHOD

Materials used for this study are,

a. Bones - 110 dry ulnae to derive formula to estimate ulnar length and 5 dry ulnae to determine the accuracy of the formulae
b. Osteometric board
c. Vernier calipers
d. Glass slide
e. Radiographs of forearm
f. Measuring rod

Collection of the bones

Hundred and ten dry ulnae (right-63, left-47) along with five dry ulnae (right-3, left-2) obtained from subjects from Tamil Nadu were used for this study. Though the bones were from cadavers dissected in the Department of Anatomy, Christian Medical College, Vellore, we could not identify which bones belonged to the same cadaver. Based on a similar study on the radius by Holla et al. (1996) the sample size was taken as 110. Defective bones were not selected for the study. The exclusion criteria were:

1. Bones having any fracture or any pathology
2. Macerated bones
3. Bones exhibiting variations

Osteometric board

An osteometric board (Fig.6) was used for measuring the whole length of the ulna. The osteometric board consists of a rectangular wooden board with a graduated scale, graduated in centimeters. The board is provided with two wooden vertical walls, one of which is fixed, at the zero end of the scale and the other movable. The other block is movable and is placed on the board. For measuring the length of the ulna, the bone is placed between the blocks as shown in the figure (Fig.7). The least count of this instrument is 1mm .The length of the ulna was measured in cm.

Vernier calipers.

For taking smaller measurements from parts of the ulna, vernier calipers (Fig.8) were used. It is a metallic instrument with two graduated scales. The main scale is graduated in cm and mm and is attached to a fixed jaw. The Vernier scale is graduated in mm and is attached to a movable jaw. The jaws are provided with extensions, which are used in the measurement of inner diameters. The least count of the instrument is 0.1 mm.

Least count of the Vernier = Magnitude of one main scale division/No. of divisions on the Vernier scale.

Total reading = M.S.R.+(V.S.R. x L.C.), where

M.S.R. = Main Scale Reading

V.S.R. = Vernier Scale Reading

L.C. = Least Count

The measurements of certain segments were done using vernier calipers as shown in the figures (Fig. 9,10 and 11).

Glass slide

For taking certain measurements from the bones, a rectangular glass slide having 0.49 cm thickness was used (Fig.11).

Points and markers

A - anterior-most point on the trochlear notch superiorly (Fig.12)

B - anterior-most point on the trochlear notch inferiorly (Fig.12)

C - superior-most point on the olecranon process (Fig.13)

D - point on the posterior aspect of ulna where the perpendicular to the long axis of the ulna passes through point A. (Fig.12)

For marking certain points on the posterior aspect of the ulna, the ulna was placed on a glass sheet of thickness 0.49 cm. The ulna was viewed from the side and points D, F and J were marked.

E - tip of the olecranon process posteriorly (Fig.13)

F - point on the posterior aspect of the ulna where the perpendicular to the long axis of the ulna passes through point B (Fig.14)

G - anterior end of the radial notch (Fig.15)

H - posterior end of the radial notch (Fig.15)

I - posterior most point of the trochlear notch (Fig.12)

J - point on the posterior aspect of ulna where the perpendicular to the long axis of the ulna passes through point I (Fig.12)

X - thickness of the glass

The following measurements of the ulna were taken using techniques recommended by Singh and Bhasin (1989). Measurements 4, 5 and 10 were made with the vernier caliper held perpendicular to the glass slide.

Measurements

One hundred and ten ulnae were taken for the study. Fourteen markers were measured from the proximal end of ulna. The data was shown in appendix (1). Mean, standard deviation and standard error of these markers and length of the bones were showed in appendix (2).

1. Distance between the anterior-most point on the trochlear notch superiorly and inferiorly (AB), (Fig. 13).
2. Distance between the superior-most point on the olecranon and anterior-most point on the coronoid process of ulna in the trochlear notch (CB), (Fig. 13).
3. Difference between CB and AB (AC), (Fig. 13).
4. 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. 12, with Marker AD)
5. 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. 12, with Marker BF)
6. Distance between the anterior and posterior ends of the radial notch (GH)
7. Distance between the tip of the olecranon process posteriorly and the anterior-most point on the radial notch distally (EG), (Fig 15)
8. Distance between the tip of the olecranon process posteriorly to the posterior-most point on the radial notch distally (EH) (Fig 10 and 15)

9. 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 14)
10. 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 11 and 12)
11. Distance between the tip of the olecranon process posteriorly to the anterior-most point on the trochlear notch inferiorly (EB) (Fig 13)
12. 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 14)
13. Distance between the anterior-most point on the trochlear notch superiorly to the tip of the olecranon process posteriorly (AE) (Fig 13)
14. 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 9)
15. Length of the ulna (L)

Measuring rod

The stature of 30 healthy individuals, 16 females and 14 males (Table 1) from South India whose ages ranged from 30-65 years was measured. Stature was measured with a measuring rod, placing the person in erect military position, barefoot and looking forwards with the back against a graduated scale. All measurements were made at the same time (2.30 pm-4 pm) to take it into account possible variations in height at different times of the day.

Study of radiographs

From the study of the bony markers it was noted that the correlation coefficient between AD and length of the ulna was 0.485. This was used for deciding the sample size for the studies of radiographs using the formula,

$$N = \frac{(Z_{1-\alpha/z} + Z_{1-\beta})^2}{[FZ(\rho_1) - FZ(\rho_0)]^2} + 3$$

ρ_0 - population correlation coefficient

ρ_1 - sample correlation coefficient

$Z_{1-\beta}$ - power

$Z_{1-\alpha/z}$ - alpha error

For the correlation coefficient 0.485, alpha error of 5%, power of 80% the required sample size was found to be 31.

X-rays were taken of the ulna of both sides of 15 individuals (4 male and 11 female). Measurements were taken of the length of the ulna and of the following parameters in the radiographs of the ulna: AD, AB, IJ and BF. These measurements were subjected to statistical analysis to study the bilateral difference. The difference was found to be insignificant at the 0.05 level. Therefore the measurements of the X-rays of only the left side of these fifteen subjects were considered for the estimation of stature. X- rays of the ulna of the right side alone were taken of another 15 individuals (10 male and 5 female). Thus a total of 30 X-rays (14 males and 16 females) were used to estimate stature (Table 1). Names of persons from whom X-rays were taken were shown in appendix (7).

Table 1: Sex – side distribution

	Male	Female
Left side	4	11
Right side	10	5

The X-rays were taken showing both ends of the ulna and bony markers were noted to estimate the stature of the individual. This was then compared with the actual stature of the individual. For measuring the maximum length of the ulna on the X-rays a horizontal line was drawn at the most distal point of the styloid process of the ulna and a second horizontal line was drawn through the most proximal point of the ulna (superior-most point of the olecranon process of the ulna) (Fig. 16). The maximum ulnar length was the distance between these two points as measured by a scale (Singh, 1973). The following bony markers: AD, AB, IJ and BF were measured in the radiograph with the help of a measuring scale and an X-ray lobby, (Fig. 16 and 17). The radiographic markers taken from 15 individuals (15 right and 15 left) showed in appendix (8). The radiographic markers taken from 30 individuals (15 right and 15 left) showed in appendix (9). Mean, standard deviation, standard error of the radiographic markers of individuals showed in appendix (10).

Statistical analysis

Between-group comparison (right and left) was done for all the bony markers and radiographic markers using independent t- test. Pearson correlation test was done to assess the correlation of the markers and length (Appendix 3, 4, 5 and 11). Regression analysis was carried out to find the markers that correlated with length. Based on the regression analysis, equations were derived for constructing the length of the ulna from the significant bony markers ($P<0.05$ was considered statistically significant). Multivariate equations were derived after excluding highly correlated markers using stepwise method. All analyses were carried out using SPSS version 11.5.

After formulating the equations to estimate the length of the ulna a restricted sample of five bones were selected. These five bones had not been taken from the set of bones used to derive the formulae. 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

Study on Bones

Range, mean and standard deviation and standard error were determined for the measurements of maximum length of ulna and the markers (Appendix-2)

Independent t-test was applied to find any significant difference in the means between the left and right ulnae (Table-2).

There was no statistically significant difference in the means of the markers.

Table 2: Independent t-test of bone markers (Right=63, Left=47)

Marker	Right		Left		Right	Left	P value
	Mean	SD	Mean	SD	SE	SE	
AB	2.08	0.23	2.10	0.22	0.29	0.32	0.628
CB	2.9	0.31	2.9	0.31	0.04	0.04	0.673
GH	1.38	0.17	1.37	0.22	0.92	0.03	0.679
EG	3.8	0.42	3.63	0.59	0.05	0.08	0.06
EH	3.61	0.58	3.7	0.34	0.07	0.05	0.28
CF	2.90	0.35	3.01	0.37	0.043	0.05	0.13
EB	3.38	3.33	0.39	0.43	0.05	0.06	0.57
AF	2.86	0.44	2.84	0.45	0.05	0.06	0.09
EA	2.10	0.32	2.08	0.25	0.04	0.03	0.70
AJ	2.47	0.30	2.41	0.25	0.38	0.36	0.29
AD	2.32	0.31	2.26	0.30	0.04	0.05	0.261
BF	3.00	0.33	3.09	0.35	0.04	0.05	0.179
IJ	1.69	1.77	1.61	2.0	0.02	0.03	0.071
Length	25.40	2.02	25.59	1.73	0.25	0.26	0.29

SD-standard deviation, SE-standard error

The correlation coefficient between the maximum length of the ulna and each of the markers was determined. The length of the ulna ‘y’ was regressed on each of the markers x and simple regression models at y = a + bX were derived, where ‘a’ is a constant (baseline) and ‘b’ is the regression coefficient.

Table 3, 4, 5 shows the markers, and their correlation with the length of the ulna.

For the ulnae of the right side:(Table-3) all the markers (AB, CB, AC, BF, EG, EH, EB, AF, EA, AJ, AD, BF, IJ, GH) show significant correlation with the length of the ulna ($p<0.05$).

For the ulnae of the left side (Table-4) the markers CB, EH, EA, AJ, AD, BF, IJ, AB, GH, and CF, show significant correlation with the length of the ulna ($p<0.05$).

For the ulnae of both side;(Table-5) all the markers (AB, CB, AC, BF, EG, EH, EB, AF, EA, AJ, AD, BF, IJ, GH) show significant correlation with the length of the ulna ($p<0.05$).

By the regression analysis simple regression equations were derived for the estimation of the length of the ulna.

Simple regression equations for the right side

Length=19.069+(3.041 AB)

Length=14.496+(3.710 CB)

Length=21.799+(4.204 AC)

Length=17.742+(5.532 GH)

Length=13.025+(3.244EG)

Length= 17.334+(2.778 CF)

Length=19.539+(1.733EB)

Length=21.339+(1.422AF)

Length=19.608+(2.753EA)

Length=19.168+(2.527AJ)

Length=17.452+(2.554BF)

Length=15.095+(6.068IJ)

Length=17.452+(3.421AD)

Length=20.029+(1.487EH)

Simple regression equations for the left side

Length= 19.693+(2.806AB)

Length= 17.141+(2.852CB)

Length= 20.749+(3.542GH)

Length=14.787+(2.908EH)

Length=19.502+(2.026CF)

Length=18.123+3.588EA)

Length=19.514+(2.529AJ)

Length=19.929+(2.513AD)

Length=14.596+(3.558BF)

Length=21.001+(2.591IJ)

Simple regression equations for both sides

Length=19.297+(2.958AB)

Length= 15.009+(3.347CB)

Length=23.145+(0.352AC)

Length=19.466+(0.834GH)

Length=18.959+(1.784FH)

Length=18.358+(2.417CF)

Length=20.980+(1.346EB)

Length=19.813+(1.517EG)

Length=22.241+(1.138AF)

Length=19.213+(2.993EA)

Length=19.47+(2.463AJ)

Length=18.68+(2.91AD)

Length=17.729+(2.55BF)

Length=16.634+(3.712IJ)

Table 3: Univariate analysis of bony markers of ulnae of the right side. Here length of the ulna (dependent variable-y) has been correlated with the bony markers (independent variables) Right side; Number=63

No	Marker	Constant	Regression Coefficient	Standard Error	P Value
1	AB	19.069	3.041	1.052	0.005*
2	CB	14.496	3.710	0.697	0.006*
3	AC (CB-AB)	21.799	4.204	1.102	0.000*
4	GH	17.742	5.532	1.354	0.001*
5	EH	20.029	1.487	0.485	0.000*
6	CF	17.334	2.778	0.658	0.000*
7	EB	19.539	1.733	0.625	0.007*
8	EG	13.025	3.244	0.447	0.000*
9	AF	21.339	1.422	0.557	0.013*
10.	EA	19.608	2.753	0.713	0.000*
11	AJ	19.168	2.527	0.786	0.000*
12	AD	17.452	3.421	0.711	0.000*
13	BF	17.729	2.554	0.658	0.000*
14	IJ	15.092	6.068	1.388	0.000*

* denotes $P<0.05$ (significant)

Table 4: Univariate analysis of bony markers of ulnae of the right side. Here length of the ulna (dependent variable-y) has been correlated with the bony markers (independent variables) Left side; Number=47

No	Marker	Constant	Regression Coefficient	Standard Error	P Value
1	AB	19.693	2.806	1.079	0.013*
2	CB	17.141	2.852	0.714	0.000*
3	AC (CB-AB)	24.148	1.648	0.865	0.064
4	GH	20.749	3.542	1.005	0.001*
5	EH	14.787	2.908	0.604	0.000*
6	CF	19.502	2.026	0.620	0.002*
7	EB	22.394	0.960	0.578	0.102
8	EG	23.879	0.473	0.428	0.275
9	AF	23.403	0.772	0.565	0.179
10.	EA	18.123	3.588	0.875	0.000*
11	AJ	19.514	2.529	0.960	0.012*
12	AD	19.929	2.513	0.744	0.002*
13	BF	14.596	3.558	0.636	0.000*
14	IJ	21.001	2.591	0.882	0.005*

* denotes $P<0.05$ (significant)

Table 5: Univariate analysis of bony markers of ulnae of both sides. Here length of the ulna (dependent variable-y) has been correlated with the bony markers (independent variables) Number= 110

No	Marker	Constant	Regression Coefficient	Standard Error	P Value
1	AB	19.297	2.958	0.753	0.000*
2	CB	15.009	3.347	0.584	0.048*
3	AC (CB-AB)	23.145	2.726	0.352	0.000*
4	GH	19.466	4.369	0.834	0.000*
5	EH	18.959	1.784	0.325	0.000*
6	CF	18.358	2.417	0.450	0.000*
7	EB	20.980	1.346	0.427	0.002*
8	EG	19.813	1.517	0.327	0.000*
9	AF	22.241	1.138	0.398	0.005*
10.	EA	19.213	2.993	0.548	0.000*
11	AJ	19.476	2.463	0.600	0.000*
12	AD	18.68	2.966	0.515	0.000*
13	BF	16.634	2.91	0.463	0.000*
14	IJ	19.059	3.712	0.765	0.000*

* denotes $P<0.05$ (significant)

The correlation between the markers was analyzed by correlation tests. This was done for bones of the both sides (Appendix; 3), right side (Appendix 4), and left side (Appendix 5). Pearson's correlation coefficient for bony markers of the right side, left side and both sides are shown below.

Pearson's correlation coefficient for bony markers of the right side

CB and AC: 0.724

AB and CB: 0.726

CB and AC: 0.659

CB and EG: 0.745

CB and EA: 0.637

CB and AD: 0.625

EG and AC: 0.622

EA and AC: 0.613

EA and EG: 0.694

AD and EG: 0.621

AJ and AF: 0.701

IJ and EG: 0.648

Pearson's correlation coefficient for bony markers of the left side

CB and AC: 0.724

EA and EH: 0.649

AJ and AF: 0.617

BF and EH: 0.665

BF and EA: 0.616

Pearson's correlation coefficient for bony markers of both sides

AB and CB: 0.615

CB and EA: 0.607

AF and AJ: 0.663

After excluding the highly correlated bony markers multiple linear regression equations were constructed using the stepwise method. Appendix (6) shows stepwise analysis of markers of both side for finding out multi-variate equation. For ulnae of the right side **EG** was the best marker to estimate the ulnar 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-6).

Table 6: Equation for finding length of ulnae of both sides from bony markers by stepwise 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

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)

Results of Study of X-Rays and Analysis

Appendix 10 shows the descriptive statistics of the radiographic markers. Mean, standard error, standard deviation of the markers and length of 30 ulnae of different individuals

Table 7 shows the independent t-test of 30 radiographs of 15 individuals (15 right, 15 left). There was no significant difference between the group means on the right and left sides of the same individuals.

Table 7: Independent t-test of radiographic markers of 15 individuals (Right=15, Left=15)

Marker	Right		Left		Right	Left	P
	Mean	SD	Mean	SD	SE	SE	value
AD	2.06	0.20	2.03	0.19	0.52	0.51	0.72
BF	3.09	0.28	2.98	0.25	0.072	0.06	0.28
IJ	1.57	0.13	1.51	0.12	0.34	0.03	0.21
AB	2.32	0.26	2.32	0.24	0.07	0.06	0.94
Length	25.52	1.96	25.36	2.04	0.51	0.53	0.82

SD-standard deviation, SE-standard error

Table 8 shows the Independent t-test of radiographic markers of 30 individuals (15 left of 15 individuals and 15 right of another 15 individuals). Only IJ and length show a significant difference between the group means.

Table 8: Independent t-tests of radiographic markers of different individuals (Right=15, Left=15)

Marker	Right		Left		Right	Left	P value
	Mean	SD	Mean	SD	SE	SE	
AD	2.7	0.21	2.03	0.2	0.53	0.05	0.66
BF	3.17	0.28	2.99	0.25	0.07	0.65	.07
IJ	1.76	0.21	1.51	0.12	0.05	0.05	0.001*
AB	2.5	0.42	2.3	0.25	0.11	0.06	0.218
Length	27.2	2.34	25.47	1.87	0.61	0.48	0.03*
Height	158.6	8.92	164.1	10.87	10.87	2.81	0.23

SD-standard deviation, SE-standard error * denotes P<0.05 (significant)

Table 9 shows the Univariate analysis of radiographic markers. The length of the ulna (dependent variable y) was analyzed against the radiographic markers (independent variable). This table shows the constant, regression coefficient, standard error, and level of significance of markers on the left side (No.=15). All the markers had a significant correlation with the length of the ulna except AD. The length of the ulna was regressed from these markers.

Table 9: Univariate analyses of radiographic markers on radiographs. Here length of the ulna (dependent variable y) analyzed against the markers (independent variable) Number 15, side: left

No.	Marker	Constant	Regression Coefficient	Standard. Error	P Value
1	AD	18.847	3.259	2.612	0.206
2	AB	12.67	5.519	1.413	0.002*
3	IJ	13.007	8.277	2.271	0.037*
4	BF	9.355	5.397	2.038	0.002*

* denotes $P<0.05$ (significant)

Table 10 shows Univariate analysis of bony markers on radiographs of the right side. The markers AD and IJ had a significant correlation with the length except AB.

Table 10: Univariate analysis of bony markers on radiographs. Here length of the ulna (dependent variable-y) analysed against the bony markers (independent variable) Number 15, side: right

No.	Marker	Constant	Regression Coefficient	Standard Error	P Value
1	AD	14.009	6.399	2.449	0.029*
2	AB	21.967	2.124	1.422	0.159
3	IJ	13.457	7.857	3.569	0.004*
4	BF	14.4	4.049	1.434	0.068

* denotes $P<0.05$ (significant)

Appendix 11 shows Pearson's correlation coefficients of radiographic markers of 30 individuals (correlation between IJ and BF is 0.65).

Table 11 shows values for the multivariate equation for finding length of ulna of both sides from radiographs after stepwise analysis (No.=30).

A multiple regression equation was derived to find out the length of the ulna from the radiographic markers after excluding highly correlated markers by stepwise analysis:

Length=3.195+(3.951AD)+(2.331AB)+(3.076BF)

Table 11: Values for the multivariate equation for finding length of ulna of both sides from radiographs after stepwise analysis (No.=30)

Model	Coefficient	Standard Error	P Value	N
AD	3.951	1.507	0.014*	30
AB	2.331	0.913	0.017*	30
BF	3.073	1.213	0.018*	30

Constant =3.195 * denotes P<0.05 (significant)

Table 12 shows the values for the equation for stature for ulnae from radiographic markers. Height=63.07+ L x 3.540

Table12: Regression equations for height from radiographic markers of 30 individuals.

Model	Coefficient	Standard error	P value
Length	3.540	0.502	0.000*

Constant=63.070 * denotes $P<0.05$ (significant)

The accuracy of the bone analysis equations was tested using a restricted sample of five ulnae. The accuracy was found to be + 0.6 –1.5cm for ulnae of both sides (Table 13) for ulnae of the right side +1.4 to –2.1cm (Table 14) and for ulnae of the left side +0.5 to +1.5cm (Table 15).

Table 13: Comparison of estimated length of the ulna with actual length (Both sides).

GH	AD	EH	CB	BF	Calculated Length	Actual Length	Difference
1.25	2.4	3.96	3.05	3.6	26.47	25.5	0.97
1.29	2.4	3.6	2.95	3.15	25.56	26.6	-1.04
1.3	2.24	3.9	3.2	3.4	26.24	25.6	0.64
1.35	2.1	3.85	2.51	3.14	24.98	26.4	-1.42
1.4	2.45	3.65	3	3.2	25.95	27.5	-1.55

Table 14 Comparison of estimated length of the ulna with actual length (Right side)

EG	Calculated Length	Actual Length	Difference
4.3	26.957	25.6	1.357
3.82	25.4018	27.5	-2.0982
3.69	24.9806	26.6	-1.6194

Table 15 Comparison of estimated length of the ulna with actual length (Left side)

BF	GH	Calculated Length	Actual Length	Difference
3.6	1.25	27	25.5	1.5
3.14	1.35	25.86	26.4	0.54

DISCUSSION

This is the first study on the estimation of stature from bony fragments of the proximal end of ulna of unknown sex and stature. The only other study on fragments of the proximal end of ulna from India was reported by Badkur and Nath (1990). In our study we measured fourteen bony markers on the proximal end of 110 ulnae (right-63, left-47) and four markers on the proximal end of the ulna on 30 radiographs. The proximal end of the ulna is less prone to destruction with the passage of time and environmental degradation (Purkait, 2001).

There was no significant difference between the means of the markers on right and left bones, in the present study, which is in accordance with previous studies by Badkur and Nath, 1990; Choi et al., 1997; and Cheng et al., 1998. Studies on the radius showed that few markers showed a significant difference between the sides (Holla et al., 1996; Selvaraj et al., 1998).

a) Estimation of length of the ulna from bony markers

All the fourteen markers of the ulna on the right side (AB, CB, AC, GH, EH, CF, EB, EG, AF, EA, AJ, AD, BF and IJ) had a significant correlation with the length of the ulna ($p<0.05$). On the left side, ten markers, i.e., AB, CB, GH, EH, CF, EA, AJ, AD, BF and IJ showed statistically significant correlation with the length of the ulna. From these markers univariate regression equations were derived for the estimation of the length of the ulna.

Badkur and Nath (1990) had studied three markers at the upper end of the ulna, i.e., height of the radial facet, height of ulnar tuberosity and breadth of olecranon. A combination of four fragmentary measurements proved to be the most effective in multiple regression equation. These four were upper shaft circumference, breadth of distal epiphysis, height of ulnar tuberosity and sagittal diameter. They derived stature equations (simple and multiple regressions) from fragment separately for males and females. The 14 markers taken for this study were different from Badkur's study. In this study sex and stature of the individuals were not known. But Badkur derived simple and multiple regression equation for estimation of length and stature for male and female separately. In this study, simple and multiple regression equations were derived for estimation of length of ulna for right, left and both sides from bony markers. For ulnae of the right side EG was the best marker to determine the ulna length using multivariate analysis. For ulnae of the left side BF and GH were the best markers for predicting the length of the ulna. For ulnae of both sides CB, BF, GH, EH, and AD were the best markers in predicting the length of the ulna. Krogman and Iscan (1986) noted that the reliability of statural estimation by using fragments depends primarily on correct determination of defined landmarks, and there is a chance that interobserver error would cause a problem.

The accuracy of the bone analysis equations was tested using a restricted sample of five ulnae. The accuracy was found to be + 0.6 to

–1.5cm for ulnae of both sides; for ulnae of the right side +1.4 to –2.1cm and for ulnae of the left side +0.5 to +1.5cm.

b) Estimation of stature from the length of the ulna

Telkka (1950) emphasized the importance of the prediction of human stature on the basis of long bones. People have estimated stature from body parts like limb segments (Cheng, 1998), entire ulna (Joshi et al., 1964) and from fragments of the radius (Holla et al., 1996). Estimation of stature from long bones is based upon the principle that the length of long bones correlates positively with stature (Prasad et al., 1996). Trotter and Gleser (1952, 1958) performed studies on the casualties of World War II and the Korean War and prepared formulae for the estimation of stature from the postmortem lengths of long bones. Forensic anthropologists are often confronted with fragmentary remains. Smaller linear segments exhibit weaker relationships to stature than larger segments (Mysorekar et al., 1982a). Deriving stature from bone length versus may be more appropriate than stature from fragment length. When a small fragment is presented, if it is only a portion of a linear segment described in literature, bone length or stature cannot be calculated using the available regression equations. It is worth having regression equations for bone length or stature that apply to smaller linear and small bony markers which may be available. The study of Badkur and Nath (1990) on 288 ulnae (82 males and 62 females) revealed a non-significant bilateral variation in the fragmentary measures of the ulna, while sex differences were highly significant. They reported that breadth of the olecranon provided the best estimate of stature in both sexes. Of the two linear measurements height of radial facet provided a better estimate of stature than the height of the ulnar tuberosity. Upper shaft circumference provided a better estimate for males while lower shaft circumference provided a better estimate for females. They reported that height of the radial facet and transverse breadth of olecranon provided the best estimate of stature for both sexes. Male ulnae exhibit greater dimensions for all the measurements than the female ones. The sexes of the ulnae in the present study were not known.

The formula derived from one racial group may be unsatisfactory when applied to another population (Trotter and Gleser, 1952; Keen, 1953). In the present study attempts to establish the age, sex and race of the individuals from whom these bones originated have not been done. Although sex and age were not considered in the present study, the statistically highly significant formulae provide a means for establishing the stature of an individual with adequate accuracy. If the age and sex were known the formulae would be more accurate (Mysorekar et al., 1982b). Vettivel et al. (1995) used the intertubercular sulcus of the humerus as a marker to indicate the length of the humerus. Prasad et al. (1996) reconstructed the length of the femur using the markers at the proximal end of the femur. Holla et al. (1996) estimated the length of the radius from markers at the distal end of the radius.

In estimating stature various factors should be borne in mind. Age has particular significance because stature increases until epiphyseal fusion at 18 to 19 yrs of age Trotter (1958), and diminishes after 30 years of age at the rate of 1.6 mm / year (Galloway, 1988).

According to Munoz (2001) the length of long bones showed greater correlation with stature in females than in males that probably reflects the more significant contribution of factors others than limb length to stature in females, such as the dimensions of the thorax and head.

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 (Trotter and Gleser, 1958).

Telka, 1950 reported that there were increases in stature with advancing generations. Actual bone measurements were first used to make a table by means of which the stature could be predicted (Orfila, 1831). Humphry (1858) made the corresponding tables in England.

Estimation of stature is a major forensic anthropological concern used in the identification of unknown and mingled human remains (Krogman and Iscan, 1986). The procedure to estimate body height is to use its components.

It has been shown that a single dimension can estimate the stature of an unknown person with great accuracy. Dimensions from the lower extremity have greater correlation with the body height than those of the upper extremity (Ozaslan et al., 2003). In order to estimate stature from fragments of long bones, the length of the long bone should be estimated initially. This is then employed in the statural formulae. Muller (1935) carried out the first work on fragmentary long bones. He worked on fragments of radii, humeri and tibiae. In 1969, Steele and McKern worked on fragments of femurs, tibiae and humeri. From these fragments they estimated the length of the individual long bones. This was later employed in the statural formulae derived by Trotter and Gleser (1958) and Genoves (1967) for Mongoloids, to estimate the stature of the individual.

C) Estimation of length of ulna and stature from radiographic markers

From the radiographs it was noted that there was a significant correlation between four markers, i.e., AD, BF, IJ and AB and the length of the ulna. Multilinear regression equations were derived to estimate the length of the ulna, and the stature of the individuals.

In the present study of radiographic markers all subjects were aged between 30-65 years and the equations derived for the ulna do not necessarily apply to younger or more elderly groups. There was no significant difference between the means of the markers of the left and the right sides when these were measured on the X-rays of the same individuals. This was similar to the findings of Purkait (2001). Multiple regression equations were derived to determine the length of the ulna from the radiographic markers. A simple linear regression was derived to determine the height of the individual form the length of the ulna. Himes et al. (1977) used radiographically measured metacarpal bone for estimating the stature in children and adults. Athawale (1963) studied the length of the ulna from twelve cadaver forearms and found that the average difference between the skiagram length and the actual length of the wet bone were statistically insignificant. Differences in measurement of stature of up to 2-5cm according to the time of the day have been reported by Genoves (1966). Body posture may also be significant in deciding stature (Snow and Williams, 1971). Accordingly in the present study all subjects were measured at the same time of the day and in same position.

CONCLUSION

In the present study fourteen bony markers on the proximal end of 110 ulnae (right-63, left-47) and four markers on the proximal end of the ulna on 30 radiographs were measured.

a) Analysis of bony markers:

Range, mean, standard deviation and standard error were determined for the measurements of the markers and for the maximum length of the ulna.

Independent t-test was applied to find any significant difference in the means between the left and right ulnae (Table-2). There was no statistically significant difference in the means of the markers.

Univariate regression analysis shows that there was a significant correlation between 14 markers (AB, CB, AC, GH, EH, CF, EB, EG, AF, EA, AJ, AD, BF and IJ) on the right side with the length of the ulna.

Univariate regression analysis shows that there was a significant correlation between 10 markers (AB, CB, GH, EH, CF, EA, AJ, AD, BF and IJ) on the left side with the length of the ulna.

Univariate regression analysis shows that there was a significant correlation between 14 markers (AB, CB, GH, EG, EH, CF, EB, AF, EA, AJ, AD, BF, IJ) on both sides with the length of the ulna.

Univariate equations were derived for estimating length of the ulna from bony fragments of upper end of ulna.

After excluding the highly correlated bony markers multiple linear regression equations were constructed using the stepwise method.

Multivariate equations

For Ulnae of the Right side: EG was the best marker to estimate the ulnar length.

Length=13.025+(3.244EG)

For Ulnae of the Left side: BF and GH were the best markers for predicting ulna length.

Length=12.821+(3.08BF)+(2.376GH)

For Ulnae of Both sides: CB, BF, GH, EH, and AD were the best markers to predict the length of the ulna.

Length=10.668+(1.171CB)+(1.325BF)+(1.614GH)+(0.707EH)+(1.099AD)

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

b) Analysis of radiographs

Range, mean, standard deviation and standard error were determined for the measurements of maximum length of the ulna and the markers.

Independent t-test was applied to find any significant difference in the means between the markers of the left and right ulnae of fifteen individuals. There was no significant difference in mean of the markers ($p<0.05$).

Independent t-test was applied to find any significant difference in the means between the markers of the left (15 subjects) and right (15 subjects) ulnae of different individuals. Only IJ and length showed a significant difference between the group means.

Univariate regression analysis of the markers showed that all the markers show a significant correlation with the length of the ulna except AD on the left side (15 subjects).

Univariate regression analysis of the markers shows that all the markers show significant correlation with the length of the ulna except AB and BFon the right side (15 subjects).

The multivariate equation for determining the length of ulna from radiographs of both sides of thirty different individuals was determined by stepwise analysis after excluding the highly correlated markers:

Length = 3.195+(3.951AD)+(2.331AB)+(3.076BF)

The regression equation for estimating height from the length of the ulna was derived from the data from X-rays of 30 individuals: Height = 63.07+ L X 3.540

Estimation of stature from ulnar fragments has potential for application in physical anthropology and forensic identification of an individual. The equations, multiplication factors and conversion tables that are widely used to convert the bone length to stature provide reasonably accurate stature estimation for forensic anthropometric purposes.

The regression values derived from the modern population of the southern part of India to estimate length of ulna can be applicable to other populations and thereby be a step to predict the stature of an individual. It has been shown that even a single bony marker for right side, the distance between the tip of the olecranon process posteriorly and the anterior -most point on the radial notch (EG) can be used to estimate the length of the ulna with great accuracy, and this can be used to estimate the stature of an unknown person.

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APPENDIX

APPENDIX – 1 Ulna measurements

Parameters																				
S.No.	Side	ab	cb	cb-ab	ad+x	bf+x	gh	eg	eh	cf	ij+x	eb	af	ea	aj	l	x	ad	bf	ij
1	1	2.2	3.49	1.29	2.95	3.75	1.55	4.71	4.8	3.61	2.31	3.99	3.53	3.39	2.88	27.2	0.49	2.46	3.26	1.82
2	1	2.24	3.11	0.87	3.15	3.42	1.33	3.62	3.8	2.69	2.13	3.68	2.9	2.1	2.55	24.3	0.49	2.66	2.93	1.64
3	1	2.3	3.14	0.84	3.3	3.75	1.79	4.39	4.4	3.49	2.31	3.79	3.5	2.34	2.83	26.8	0.49	2.81	3.26	1.82
4	1	2.05	2.73	0.68	2.31	3.32	1.2	3.55	3.41	2.64	2.1	3.1	2.89	1.82	2.5	25.5	0.49	1.82	2.83	1.61
5	2	2.2	2.95	0.75	2.45	3.43	1.52	3.8	3.61	3.1	2.09	3.39	3.2	1.91	2.53	27.9	0.49	1.96	2.94	1.6
6	2	2	2.35	0.35	2.8	3.59	1.54	3.6	3.24	2.42	2.1	3.18	2.72	1.88	2.79	26.1	0.49	2.31	3.1	1.61
7	1	2	2.99	0.99	3.14	3.69	1.4	4.1	3.8	2.95	2.4	3.59	3.4	2.34	2.89	27.3	0.49	2.65	3.2	1.91
8	1	2.12	3.5	1.38	3.31	3.91	1.69	4.28	3.87	3.5	2.29	4.1	3.41	2.5	2.91	28.7	0.49	2.82	3.42	1.8
9	2	2.14	2.99	0.85	2.49	3.29	1.25	3.55	3.59	2.85	2.1	3.31	2.9	1.9	2.41	24.3	0.49	2	2.8	1.61
10	1	1.88	3.14	1.26	2.8	3.35	1.46	3.89	3.95	3.4	2.35	3.55	3.4	2.14	2.64	27.6	0.49	2.31	2.86	1.86
11	1	1.99	2.91	0.92	3	3.65	1.55	4.04	3.99	3.09	2.28	3.5	3.9	2.14	2.49	23.8	0.49	2.51	3.16	1.79
12	1	2.75	3.65	0.9	3.05	4.23	1.7	4.5	4.23	2.8	2.35	2.41	3.67	2.5	2.71	30	0.49	2.56	3.74	1.86
13	1	2.1	2.7	0.6	2.78	3.2	1.55	3.39	3.28	2.59	1.88	2.99	2.61	1.65	2.41	22	0.49	2.29	2.71	1.39
14	1	2.33	2.9	0.57	2.55	3.2	1.2	3.3	3.14	2.6	2.25	3.05	2.59	1.6	2.21	22.2	0.49	2.06	2.71	1.76
15	1	2.49	3.1	0.61	2.6	3.55	1.36	3.28	3.24	2.8	2.2	3.09	3.19	1.9	2.59	21	0.49	2.11	3.06	1.71
16	1	1.95	2.78	0.83	2.8	3.46	1.4	3.9	3.5	2.6	2.55	3.23	2.69	1.96	2.43	25.8	0.49	2.31	2.97	2.06
17	1	2.19	3	0.81	2.9	3.71	1.5	4.2	4	3	2.29	3.52	2.98	2.13	2.49	27.5	0.49	2.41	3.22	1.8
18	1	1.9	2.73	0.83	2.8	3.5	1.5	3.69	3.6	2.9	2.1	3.1	2.39	2.02	2.53	24.8	0.49	2.31	3.01	1.61
19	1	2.09	2.8	0.71	2.74	3.38	1.29	3.78	3.64	2.83	2.14	3.34	2.91	1.95	2.6	24	0.49	2.25	2.89	1.65
20	1	2	2.95	0.95	2.82	3.84	1.7	4.19	3.9	2.99	2.32	3.62	3.12	2.39	2.7	26	0.49	2.33	3.35	1.83
21	1	1.9	2.99	1.09	2.79	3.29	1.55	4.1	4.14	2.9	2.2	3.35	2.7	2	2.59	26.4	0.49	2.3	2.8	1.71
22	1	1.64	2.41	0.77	2.5	2.95	1.36	3.5	3.5	2.55	1.97	2.97	2.19	1.64	1.89	23	0.49	2.01	2.46	1.48
23	1	2	2.76	0.76	2.69	3.48	1.4	3.73	3.55	2.5	2.25	3.23	2.2	1.74	2.05	26	0.49	2.2	2.99	1.76
24	1	2.23	2.99	0.76	2.9	3.45	1.59	3.78	3.6	3.88	2	3.4	2.19	1.86	2.14	27	0.49	2.41	2.96	1.51
25	1	2.54	3.34	0.8	3.06	3.3	1.38	4.2	3.95	3.2	2.2	3.87	2.5	2.41	2.77	26.5	0.49	2.57	2.81	1.71
26	1	1.96	2.68	0.72	2.83	3.21	1.34	3.65	3.3	2.8	2.09	3.3	2.85	2.2	2.5	25.7	0.49	2.34	2.72	1.6
27	1	2.4	3	0.6	2.85	3.35	1.24	3.8	3.73	3	2.13	3.5	2.75	2	2.09	25.9	0.49	2.36	2.86	1.64
28	1	2.3	3.3	1	3.1	3.65	1.44	4.1	3.87	3.4	2.3	3.6	2.34	2.14	2.39	26.9	0.49	2.61	3.16	1.81
29	1	2.13	2.81	0.68	2.8	3.34	1.5	4	3.91	3.04	2.3	3.51	2.9	2.1	2.31	25.8	0.49	2.31	2.85	1.81
30	1	2.11	2.69	0.58	2.21	2.9	1.14	3.49	3.5	2.64	1.99	3.15	2.88	2	2	23	0.49	1.72	2.41	1.5
31	1	2.24	3.35	1.11	2.89	3.7	1.41	4.41	4.21	2.9	2.44	4	2.25	2.3	2.4	25	0.49	2.4	3.21	1.95
32	1	2.1	3.2	1.1	3.09	3.65	1.25	4.4	4.6	2.2	2.49	3.64	2.4	2.52	2.45	27.5	0.49	2.6	3.16	2
33	1	2.5	3.05	0.55	2.75	3.35	1.38	3.4	3.36	2.55	2.01	3.33	2.14	2	2.1	23.5	0.49	2.26	2.86	1.52
34	1	1.8	2.5	0.7	2.49	3.43	1.15	2.42	3.35	2.8	2.15	2.9	2.89	1.6	2.85	24.1	0.49	2	2.94	1.66
35	1	2.29	3.35	1.06	3.39	4.13	1.5	4.44	4.14	3.13	2.24	3.86	3.49	2.3	2.51	27.1	0.49	2.9	3.64	1.75
36	1	2	2.8	0.8	2.7	3.7	1.52	4	3.25	2.8	2.35	3.46	2.26	2.14	2.26	25.2	0.49	2.21	3.21	1.86
37	1	1.91	2.75	0.84	2.79	3.45	1.61	3.68	3.25	2.79	2.25	3.35	2.25	2	1.74	24.7	0.49	2.3	2.96	1.76
38	2	2.6	3.35	0.75	2.8	4.03	1.29	4.04	4.21	3.31	2.5	3.91	2.8	2.5	2.45	26.9	0.49	2.31	3.54	2.01
39	2	1.91	2.74	0.83	3.28	3.65	1.75	3.9	3.99	3.4	2.4	3.55	2.39	2.25	2.33	27.6	0.49	2.79	3.16	1.91
40	2	1.91	3.36	1.45	2.95	3.69	1.51	3.68	3.9	3.15	2.34	3.4	2.2	2.11	2.21	26	0.49	2.46	3.2	1.85
41	2	2.01	2.9	0.89	2.9	3.91	1.5	3.81	3.95	3.1	2.38	2.15	2.25	1.9	2.7	26.9	0.49	2.41	3.42	1.89

42	2	2.03	3.1	1.07	3.45	3.75	1.3	3.5	3.81	3.28	1.85	3.49	2.42	2	2.2	27.1	0.49	2.96	3.26	1.36
43	2	2.19	2.9	0.71	2.6	3.45	1.24	1.25	3.54	3.6	3.55	3.39	2.14	1.9	2.11	26.2	0.49	2.11	2.96	3.06
44	2	2.4	2.75	0.35	2.72	3.09	1.23	3.1	3.41	2.74	2.15	3.15	2.2	2.1	2.19	23.7	0.49	2.23	2.6	1.66
45	2	2.13	3.09	0.96	2.76	3.5	1.29	3.7	3.8	3.2	2.26	3.59	2.44	2.39	2.54	26.2	0.49	2.27	3.01	1.77
46	2	1.85	2.9	1.05	2.8	3.54	1.33	3.84	4.03	3.13	2.35	3.5	2.35	2.15	2.25	23.5	0.49	2.31	3.05	1.86
47	2	2.2	2.98	0.78	2.62	3.6	1.34	3.94	4.08	2.2	2.13	3.5	2.3	1.89	2.19	26.9	0.49	2.13	3.11	1.64
48	2	2.13	3	0.87	2.64	3.74	1.2	3.75	3.91	3.1	2.33	3.5	3.09	2.1	2.49	24.9	0.49	2.15	3.25	1.84
49	1	1.8	2.64	0.84	2.6	3.5	1.2	3.7	3.51	2.9	2.2	2.9	2.1	1.88	2.05	25.6	0.49	2.11	3.01	1.71
50	2	2.09	2.99	0.9	3	3.5	1.5	3.64	3.8	2.69	2.2	3.6	2.3	2.24	2.35	26.9	0.49	2.51	3.01	1.71
51	2	1.9	2.91	1.01	2.74	3.7	1.3	3.84	3.9	3.3	2.3	3.3	3.25	2.2	2.14	25.7	0.49	2.25	3.21	1.81
52	2	2.14	2.89	0.75	2.88	3.73	1.35	3.81	3.9	2.95	2.3	3.19	2.5	2.2	2.25	24.2	0.49	2.39	3.24	1.81
53	2	2.09	2.63	0.54	2.7	3.49	1.11	3.34	3.28	2.6	2.19	3.29	2.09	1.91	2.31	24.1	0.49	2.21	3	1.7
54	2	1.82	2.62	0.8	2.29	3.52	1.2	3.5	3.3	2.2	2.22	3.05	2.1	1.9	1.85	25.5	0.49	1.8	3.03	1.73
55	2	2.15	2.91	0.76	2.7	4.1	1.64	4.05	3.34	3.23	2.5	3.55	3.36	2.3	2.7	26.7	0.49	2.21	3.61	2.01
56	2	2.1	2.79	0.69	2.5	3.64	1.17	3.6	3.58	3	2.23	2.15	3.1	1.79	2.55	28.5	0.49	2.01	3.15	1.74
57	2	1.84	2.59	0.75	3.05	3.58	1.15	3.44	3.3	2.94	2.13	3.11	2.89	1.89	2.05	25.5	0.49	2.56	3.09	1.64
58	2	2.1	2.8	0.7	2.55	3.54	1.49	3.79	3.5	3.15	2.19	3.39	3.14	1.94	2.3	25.2	0.49	2.06	3.05	1.7
59	2	2.19	3.22	1.03	2.7	3.7	1.8	3.8	3.55	2.9	2.35	2.64	3.14	2.2	2.3	27	0.49	2.21	3.21	1.86
60	2	2.1	3.05	0.95	2.8	3.68	1.5	3.8	3.7	3.1	2.1	3.5	2.44	2.3	2.15	24.3	0.49	2.31	3.19	1.61
61	2	2.09	2.96	0.87	2.79	3.91	1.29	4	4.04	3.2	2.6	3.5	3.32	2.4	2.45	27.5	0.49	2.3	3.42	2.11
62	1	2.25	3.33	1.08	3.09	3.69	1.2	3.7	3.81	3.44	1.95	3.7	2.25	1.9	2.2	27.3	0.49	2.6	3.2	1.46
63	1	2.2	2.71	0.51	2.51	3.39	1.2	3.4	3.14	2.5	2.15	3.23	2.21	1.89	2.3	23.9	0.49	2.02	2.9	1.66
64	12	2	2.59	0.59	2.39	3.26	1.2	3.39	3.17	2.4	2	3	2.4	1.8	1.83	29.7	0.49	1.9	2.77	1.51
65	2	1.59	2.3	0.71	2.3	2.85	1	3.32	3.2	2.65	1.92	2.8	2.69	1.75	2.19	23.3	0.49	1.81	2.36	1.43
66	2	2.15	3.19	1.04	2.9	3.41	1.5	4.11	3.91	2.14	2.19	3.28	2.39	2.54	2.43	27.3	0.49	2.41	2.92	1.7
67	2	1.71	2.41	0.7	2.8	3.49	1.53	3.1	3.5	2.95	2.35	3	3	1.9	2.45	23	0.49	2.31	3	1.86
68	2	2.19	2.5	0.31	2.75	3.19	1.3	3.49	3.39	2.79	2.13	2.9	2.85	1.55	2.29	22.3	0.49	2.26	2.7	1.64
69	2	2.3	3.2	0.9	3.41	3.95	1.3	4	4.15	3.34	2.73	3.85	3.41	2.2	2.25	28	0.49	2.92	3.46	2.24
70	2	2.29	3.21	0.92	2.89	3.6	2.31	1.23	3.94	3.79	2.31	2.95	2.69	2.3	2.7	28.3	0.49	2.4	3.11	1.82
71	2	2.2	2.74	0.54	2.5	3.3	1.33	3.63	3.64	2.85	2.14	3.2	3	1.9	2.5	23.3	0.49	2.01	2.81	1.65
72	2	2.7	3.45	0.75	2.8	4.16	1.31	4.38	4.3	3.39	2.4	4.05	3.51	2.2	2.99	27.5	0.49	2.31	3.67	1.91
73	1	2.1	3.05	0.95	3.59	2.12	1.5	3.8	3.71	3.1	2.12	3.5	3	2.11	2.64	26.5	0.49	3.1	1.63	1.63
74	1	2.25	2.8	0.55	2.5	3.53	1.25	3.35	3.34	2.72	1.94	3.3	2.9	2	2.2	22.8	0.49	2.01	3.04	1.45
75	2	2.44	3.5	1.06	2.84	4.3	1.13	4.09	3.9	3.68	2.32	3.82	3.8	2.51	3.15	26.1	0.49	2.35	3.81	1.83
76	2	2.23	2.73	0.5	2.3	3.05	1.29	3.2	3.1	2.8	2.05	3.05	3	1.49	2.29	22.5	0.49	1.81	2.56	1.56
77	2	2.01	3	0.99	2.8	3.6	1.42	4.3	4.51	3.1	2.39	4.64	3.31	2.21	2.62	26.5	0.49	2.31	3.11	1.9
78	2	2.49	3.35	0.86	2.82	4	1.75	4.29	3.8	3.25	2.41	3.84	3.31	2.19	2.7	27	0.49	2.33	3.51	1.92
79	1	1.69	2.41	0.72	2.3	2.84	1.12	3.05	2.79	2.25	1.75	2.81	2.35	1.8	2	21.7	0.49	1.81	2.35	1.26
80	2	2.01	3.05	1.04	2.8	4	1.4	4.13	4.35	3.35	2.29	3.45	3.32	2.15	2.5	26	0.49	2.31	3.51	1.8
81	2	2.25	2.99	0.74	2.45	3.14	1.29	3.41	3.21	2.84	1.91	3.11	3	1.7	2.41	23.4	0.49	1.96	2.65	1.42
82	1	2.19	3.1	0.91	2.95	3.73	1.4	4.04	3.81	3	2.09	3.64	3.24	2.13	2.64	24.8	0.49	2.46	3.24	1.6
83	1	1.94	3	1.06	3	3.69	1.41	4.28	4.11	3.22	2.31	3.8	3.21	2.4	3.3	26.5	0.49	2.51	3.2	1.82
84	1	1.8	2.94	1.14	3.05	3.65	1.21	3.64	3.52	2.72	2.15	3.25	2.89	2.28	2.7	24.2	0.49	2.56	3.16	1.66
85	2	2.3	2.96	0.66	2.75	3.81	1.5	4	3.84	3.25	2.35	3.64	3.34	2.34	2.55	26.7	0.49	2.26	3.32	1.86
86	1	2	2.72	0.72	2.89	3.7	1.33	3.7	3.75	3.65	2.39	3.49	3.14	2.09	2.6	25.5	0.49	2.4	3.21	1.9
87	1	2.21	3.25	1.04	2.64	3.5	1.23	3.7	3.42	2.92	2.21	3.64	3	2.19	2.4	23	0.49	2.15	3.01	1.72
88	1	2	3.23	1.23	2.9	2.69	1.3	4	3.58	3.01	2.31	3.6	3.1	2.15	2.54	26.1	0.49	2.41	2.2	1.82
89	1	1.6	2.4	0.8	2.6	3.19	1.2	3.2	3.04	2.4	2	2.8	2.45	1.89	2.13	21.7	0.49	2.11	2.7	1.51
90	1	2.04	3	0.96	2.59	3.7	1.4	3.8	3.2	2.9	2.29	3.4	3	3.3	2.45	25.3	0.49	2.1	3.21	1.8
91	1	1.85	2.8	0.95	2.82	3.41	1.33	3.74	3.31	2.85	1.99	3.49	2.9	2.03	2.49	25.6	0.49	2.33	2.92	1.5
92	1	2.05	2.79	0.74	2.84	3.55	1.49	3.85	3.73	2.73	2.23	3.4	2.9	2.1	2.5	27.5	0.49	2.35	3.06	1.74

93	1	2.02	2.7	0.68	2.8	3.35	1.28	3.7	3.68	2.7	2.03	3.39	2.91	1.93	2.4	23.5	0.49	2.31	2.86	1.54
94	1	1.85	2.6	0.75	2.51	3.1	1.1	3.21	3.1	2.71	2.1	3.2	2.81	1.85	2.3	23.7	0.49	2.02	2.61	1.61
95	2	2.2	3.12	0.92	2.55	3.75	1.3	3.89	4.1	3.1	2.5	3.75	3.35	2.51	2.9	25.6	0.49	2.06	3.26	2.01
96	1	2.11	2.99	0.88	2.71	3.72	1.1	3.9	3.91	2.73	2.1	3.5	3	2.1	2.5	26.2	0.49	2.22	3.23	1.61
97	2	2.05	2.81	0.76	2.25	3.44	1.1	3.5	3.43	2.41	2.09	3.1	2.53	1.8	2.05	23.5	0.49	1.76	2.95	1.6
98	1	1.7	2.6	0.9	1.61	3.3	1.3	3.42	3.31	2.5	2.24	3.1	2.55	1.95	2.3	22.7	0.49	1.12	2.81	1.75
99	2	1.73	2.59	0.86	2.53	3.05	1	3.41	3.25	2.5	1.9	3.05	2.64	2	2.2	22.3	0.49	2.04	2.56	1.41
100	1	2.09	3.33	1.24	3.31	3.89	1.2	4.19	0.4	3.05	2.35	3.8	3.31	2.5	2.9	25.7	0.49	2.82	3.4	1.86
101	1	2.23	3.23	1	3.15	4.09	1.5	4.1	3.8	3.21	2.35	3.78	3.4	2.44	2.89	27.1	0.49	2.66	3.6	1.86
102	1	1.65	2.4	0.75	2.69	3.39	1.3	3.3	3.3	2.59	2	2.9	2.7	1.8	2.32	21.7	0.49	2.2	2.9	1.51
103	1	2.13	3.1	0.97	2.82	3.85	1.42	4.53	4.4	3.2	2.2	3.85	3.4	2.21	2.65	26.6	0.49	2.33	3.36	1.71
104	1	2.28	3.34	1.06	3.2	4.15	1.64	4.49	4.28	3	2.49	3.7	3.35	2.3	2.9	28.5	0.49	2.71	3.66	2
105	1	1.9	2.59	0.69	2.63	3.15	1.19	3.3	3.1	2.8	1.91	3	2.85	1.71	2.26	24.3	0.49	2.14	2.66	1.42
106	2	1.79	3.94	2.15	2.8	3.25	1.42	3.65	3.35	2.81	2	3.35	3.09	2.04	2.45	25.1	0.49	2.31	2.76	1.51
1O7	2	1.8	2.7	0.9	2.5	3.32	1.29	3.5	3.32	2.8	1.94	3.14	2.9	2.04	2.35	23.8	0.49	2.01	2.83	1.45
108	1	2.19	2.94	0.75	2.44	3.59	1.25	3.85	3.75	3.2	2.15	1.89	3.15	1.8	2.5	26.9	0.49	1.95	3.1	1.66
109	2	2.1	3.5	1.4	3.85	3.61	1.42	4.15	4.1	3.6	2.26	3.68	3.35	2.4	2.6	26.9	0.49	3.36	3.12	1.77
110	1	2.51	3.4	0.89	2.8	3.91	1.71	4.05	4.1	3.19	2.3	3.9	3.4	2.2	2.8	27.3	0.49	2.31	3.42	1.81

APPENDIX – 2

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std.
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
AB	110	1.59	2.75	2.0918	.0216	.22685
CB	110	2.30	3.94	2.9503	.0293	.30733
CB_AB	110	.31	2.15	.8585	.0234	.24521
AD_X	110	1.61	3.85	2.7846	.0296	.31033
BF_X	110	2.12	4.30	3.5317	.0322	.33745
GH	110	1.00	2.31	1.3779	.0186	.19543
EG	110	1.23	4.71	3.7376	.0486	.50975
EH	110	.40	4.80	3.6580	.0473	.49635
CF	110	2.14	3.88	2.9489	.0344	.36074
IJ_X	110	1.75	3.55	2.2212	.0206	.21626
EB	110	1.89	4.64	3.3633	.0390	.40890
AF	110	2.09	3.90	2.8513	.0422	.44237
EA	110	1.49	3.39	2.0956	.0281	.29510
AJ	110	1.74	3.30	2.4405	.0270	.28306
L	110	21.00	30.00	25.4855	.1809	1.89775
AD	110	1.12	3.36	2.2946	.0296	.31033
BF	110	1.63	3.81	3.0417	.0322	.33745
IJ	110	1.26	3.06	1.7312	.0206	.21626
Valid N (listwise)	110					

APPENDIX – 3 PEARSON CORRELATION OF BONY MARKERS OF 110 ULNAE

Correlations

		AB	CB	CB_AB	AD_X	BF_X	GH	EG	EH	CF	IJ_X	EB	AF	EA	AJ	L	X	AD	BF	IJ
AB	Pearson Correlation	1	.615**	-.154	.250**	.417**	.258**	.253**	.307**	.338**	.272**	.311**	.276**	.288**	.318**	.354**	.[a]	.250**	.417**	.272**
	Sig. (2-tailed)	.	.000	.108	.008	.000	.006	.008	.001	.000	.004	.001	.003	.002	.001	.000	.	.008	.000	.004
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
CB	Pearson Correlation	.615**	1	.684**	.533**	.506**	.368**	.477**	.413**	.506**	.330**	.520**	.403**	.607**	.477**	.542**	.[a]	.533**	.506**	.330**
	Sig. (2-tailed)	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
CB_AB	Pearson Correlation	-.154	.684**	1	.436**	.248**	.222*	.363**	.233*	.321**	.161	.364**	.249**	.494**	.303**	.352**	.[a]	.436**	.248**	.161
	Sig. (2-tailed)	.108	.000	.	.000	.009	.020	.000	.014	.001	.092	.000	.009	.000	.001	.000	.	.000	.009	.092
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
AD_X	Pearson Correlation	.250**	.533**	.436**	1	.343**	.393**	.409**	.315**	.476**	.241*	.466**	.251**	.451**	.386**	.485**	.[a]	1.000**	.343**	.241*
	Sig. (2-tailed)	.008	.000	.000	.	.000	.000	.000	.001	.000	.011	.000	.008	.000	.000	.000	.	.	.000	.011
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
BF_X	Pearson Correlation	.417**	.506**	.248**	.343**	1	.331**	.441**	.374**	.444**	.474**	.341**	.401**	.505**	.449**	.517**	.[a]	.343**	1.000**	.474**
	Sig. (2-tailed)	.000	.000	.009	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
GH	Pearson Correlation	.258**	.368**	.222*	.393**	.331**	1	.163	.353**	.403**	.255**	.187	.208*	.345**	.324**	.450**	.[a]	.393**	.331**	.255**
	Sig. (2-tailed)	.006	.000	.020	.000	.000	.	.090	.000	.000	.007	.050	.029	.000	.001	.000	.	.000	.000	.007
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
EG	Pearson Correlation	.253**	.477**	.363**	.409**	.441**	.163	1	.407**	.158	.058	.480**	.423**	.508**	.389**	.408**	.[a]	.409**	.441**	.058
	Sig. (2-tailed)	.008	.000	.000	.000	.000	.090	.	.000	.100	.548	.000	.000	.000	.000	.000	.	.000	.000	.548
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
EH	Pearson Correlation	.307**	.413**	.233*	.315**	.374**	.353**	.407**	1	.381**	.319**	.361**	.238*	.375**	.282**	.467**	.[a]	.315**	.374**	.319**
	Sig. (2-tailed)	.001	.000	.014	.001	.000	.000	.000	.	.000	.001	.000	.012	.000	.003	.000	.	.001	.000	.001
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
CF	Pearson Correlation	.338**	.506**	.321**	.476**	.444**	.403**	.158	.381**	1	.423**	.402**	.427**	.395**	.433**	.459**	.[a]	.476**	.444**	.423**
	Sig. (2-tailed)	.000	.000	.001	.000	.000	.000	.100	.000	.	.000	.000	.000	.000	.000	.000	.	.000	.000	.000
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
IJ_X	Pearson Correlation	.272**	.330**	.161	.241*	.474**	.255**	.058	.319**	.423**	1	.316**	.186	.390**	.271**	.423**	.[a]	.241*	.474**	1.000**
	Sig. (2-tailed)	.004	.000	.092	.011	.000	.007	.548	.001	.000	.	.001	.051	.000	.004	.000	.	.011	.000	.
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
EB	Pearson Correlation	.311**	.520**	.364**	.466**	.341**	.187	.480**	.361**	.402**	.316**	1	.302**	.544**	.371**	.290**	.[a]	.466**	.341**	.316**
	Sig. (2-tailed)	.001	.000	.000	.000	.000	.050	.000	.000	.000	.001	.	.001	.000	.000	.002	.	.000	.000	.001
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
AF	Pearson Correlation	.276**	.403**	.249**	.251**	.401**	.208*	.423**	.238*	.427**	.186	.302**	1	.386**	.663**	.265**	.[a]	.251**	.401**	.186
	Sig. (2-tailed)	.003	.000	.009	.008	.000	.029	.000	.012	.000	.051	.001	.	.000	.000	.005	.	.008	.000	.051
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
EA	Pearson Correlation	.288**	.607**	.494**	.451**	.505**	.345**	.508**	.375**	.395**	.390**	.544**	.386**	1	.494**	.465**	.[a]	.451**	.505**	.390**
	Sig. (2-tailed)	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.000	.	.000	.000	.000
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
AJ	Pearson Correlation	.318**	.477**	.303**	.386**	.449**	.324**	.389**	.282**	.433**	.271**	.371**	.663**	.494**	1	.367**	.[a]	.386**	.449**	.271**
	Sig. (2-tailed)	.001	.000	.001	.000	.000	.001	.000	.003	.000	.004	.000	.000	.000	.	.000	.	.000	.000	.004
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
L	Pearson Correlation	.354**	.542**	.352**	.485**	.517**	.450**	.408**	.467**	.459**	.423**	.290**	.265**	.465**	.367**	1	.[a]	.485**	.517**	.423**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.005	.000	.000	.	.	.000	.000	.000
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
X	Pearson Correlation	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]
	Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
AD	Pearson Correlation	.250**	.533**	.436**	1.000**	.343**	.393**	.409**	.315**	.476**	.241*	.466**	.251**	.451**	.386**	.485**	.[a]	1	.343**	.241*
	Sig. (2-tailed)	.008	.000	.000	.	.000	.000	.000	.001	.000	.011	.000	.008	.000	.000	.000	.	.	.000	.011
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
BF	Pearson Correlation	.417**	.506**	.248**	.343**	1.000**	.331**	.441**	.374**	.444**	.474**	.341**	.401**	.505**	.449**	.517**	.[a]	.343**	1	.474**
	Sig. (2-tailed)	.000	.000	.009	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	.000	.	.000
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
IJ	Pearson Correlation	.272**	.330**	.161	.241*	.474**	.255**	.058	.319**	.423**	1.000**	.316**	.186	.390**	.271**	.423**	.[a]	.241*	.474**	1
	Sig. (2-tailed)	.004	.000	.092	.011	.000	.007	.548	.001	.000	.	.001	.051	.000	.004	.000	.	.011	.000	.
	N	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.

APPENDIX – 4 PEARSON CORRELATION OF BONY MARKERS OF 63 ULNAE (RIGHT SIDE)

Correlations[a]

		AB	CB	CB_AB	GH	EG	EH	CF	EB	AF	EA	AJ	AD	BF	IJ
AB	Pearson Correlation	1	.726**	-.038	.330**	.422**	.295*	.333**	.278*	.260*	.286*	.226	.379**	.388**	.250*
	Sig. (2-tailed)	.	.000	.769	.008	.001	.019	.008	.028	.040	.023	.075	.002	.002	.048
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63
CB	Pearson Correlation	.726**	1	.659**	.423**	.745**	.387**	.574**	.582**	.465**	.637**	.495**	.625**	.511**	.530**
	Sig. (2-tailed)	.000	.	.000	.001	.000	.002	.000	.000	.000	.000	.000	.000	.000	.000
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63
CB_AB	Pearson Correlation	-.038	.659**	1	.254*	.622**	.240	.470**	.542**	.391**	.613**	.472**	.495**	.318*	.497**
	Sig. (2-tailed)	.769	.000	.	.045	.000	.058	.000	.000	.002	.000	.000	.000	.011	.000
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63
GH	Pearson Correlation	.330**	.423**	.254*	1	.597**	.454**	.445**	.348**	.357**	.376**	.385**	.477**	.409**	.427**
	Sig. (2-tailed)	.008	.001	.045	.	.000	.000	.000	.005	.004	.002	.002	.000	.001	.000
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63
EG	Pearson Correlation	.422**	.745**	.622**	.597**	1	.523**	.510**	.595**	.459**	.694**	.493**	.621**	.556**	.648**
	Sig. (2-tailed)	.001	.000	.000	.000	.	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63
EH	Pearson Correlation	.295*	.387**	.240	.454**	.523**	1	.339**	.291*	.255*	.292*	.255*	.261*	.257*	.314*
	Sig. (2-tailed)	.019	.002	.058	.000	.000	.	.007	.021	.044	.020	.043	.039	.042	.012
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63
CF	Pearson Correlation	.333**	.574**	.470**	.445**	.510**	.339**	1	.481**	.432**	.396**	.440**	.501**	.335**	.301*
	Sig. (2-tailed)	.008	.000	.000	.000	.000	.007	.	.000	.000	.001	.000	.000	.007	.016
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63
EB	Pearson Correlation	.278*	.582**	.542**	.348**	.595**	.291*	.481**	1	.285*	.551**	.426**	.576**	.313*	.424**
	Sig. (2-tailed)	.028	.000	.000	.005	.000	.021	.000	.	.024	.000	.000	.000	.013	.001
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63
AF	Pearson Correlation	.260*	.465**	.391**	.357**	.459**	.255*	.432**	.285*	1	.482**	.701**	.398**	.415**	.369**
	Sig. (2-tailed)	.040	.000	.002	.004	.000	.044	.000	.024	.	.000	.000	.001	.001	.003
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63
EA	Pearson Correlation	.286*	.637**	.613**	.376**	.694**	.292*	.396**	.551**	.482**	1	.520**	.435**	.464**	.528**
	Sig. (2-tailed)	.023	.000	.000	.002	.000	.020	.001	.000	.000	.	.000	.000	.000	.000
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63
AJ	Pearson Correlation	.226	.495**	.472**	.385**	.493**	.255*	.440**	.426**	.701**	.520**	1	.535**	.453**	.487**
	Sig. (2-tailed)	.075	.000	.000	.002	.000	.043	.000	.000	.000	.000	.	.000	.000	.000
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63
AD	Pearson Correlation	.379**	.625**	.495**	.477**	.621**	.261*	.501**	.576**	.398**	.435**	.535**	1	.324**	.379**
	Sig. (2-tailed)	.002	.000	.000	.000	.000	.039	.000	.000	.001	.000	.000	.	.010	.002
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63
BF	Pearson Correlation	.388**	.511**	.318*	.409**	.556**	.257*	.335**	.313*	.415**	.464**	.453**	.324**	1	.507**
	Sig. (2-tailed)	.002	.000	.011	.001	.000	.042	.007	.013	.001	.000	.000	.010	.	.000
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63
IJ	Pearson Correlation	.250*	.530**	.497**	.427**	.648**	.314*	.301*	.424**	.369**	.528**	.487**	.379**	.507**	1
	Sig. (2-tailed)	.048	.000	.000	.000	.000	.012	.016	.001	.003	.000	.000	.002	.000	.
	N	63	63	63	63	63	63	63	63	63	63	63	63	63	63

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. SIDE_R = Right

APPENDIX – 5 PEARSON CORRELATION OF BONY MARKERS OF 47 ULNAE (LEFT SIDE)

Correlations[a]

		AB	CB	CB_AB	GH	EG	EH	CF	EB	AF	EA	AJ	AD	BF	IJ
AB	Pearson Correlation	1	.460**	-.279	.196	.121	.350*	.340*	.361*	.301*	.302*	.496**	.087	.459**	.302*
	Sig. (2-tailed)	.	.001	.057	.186	.419	.016	.019	.013	.040	.039	.000	.561	.001	.039
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47
CB	Pearson Correlation	.460**	1	.724**	.326*	.264	.504**	.423**	.454**	.324*	.575**	.473**	.428**	.501**	.182
	Sig. (2-tailed)	.001	.	.000	.025	.072	.000	.003	.001	.026	.000	.001	.003	.000	.221
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47
CB_AB	Pearson Correlation	-.279	.724**	1	.200	.192	.274	.193	.210	.116	.388**	.126	.395**	.185	-.038
	Sig. (2-tailed)	.057	.000	.	.178	.195	.063	.193	.156	.438	.007	.400	.006	.214	.801
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47
GH	Pearson Correlation	.196	.326*	.200	1	-.157	.275	.388**	.040	.063	.333*	.266	.313*	.276	.169
	Sig. (2-tailed)	.186	.025	.178	.	.292	.061	.007	.791	.673	.022	.071	.032	.060	.255
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47
EG	Pearson Correlation	.121	.264	.192	-.157	1	.392**	-.095	.383**	.408**	.331*	.272	.196	.415**	-.234
	Sig. (2-tailed)	.419	.072	.195	.292	.	.006	.525	.008	.004	.023	.064	.187	.004	.114
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47
EH	Pearson Correlation	.350*	.504**	.274	.275	.392**	1	.484**	.577**	.233	.649**	.421**	.516**	.665**	.391**
	Sig. (2-tailed)	.016	.000	.063	.061	.006	.	.001	.000	.116	.000	.003	.000	.000	.007
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47
CF	Pearson Correlation	.340*	.423**	.193	.388**	-.095	.484**	1	.341*	.437**	.432**	.490**	.499**	.578**	.504**
	Sig. (2-tailed)	.019	.003	.193	.007	.525	.001	.	.019	.002	.002	.000	.000	.000	.000
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47
EB	Pearson Correlation	.361*	.454**	.210	.040	.383**	.577**	.341*	1	.322*	.554**	.292*	.328*	.411**	.273
	Sig. (2-tailed)	.013	.001	.156	.791	.008	.000	.019	.	.027	.000	.047	.025	.004	.063
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47
AF	Pearson Correlation	.301*	.324*	.116	.063	.408**	.233	.437**	.322*	1	.228	.617**	.054	.394**	.058
	Sig. (2-tailed)	.040	.026	.438	.673	.004	.116	.002	.027	.	.124	.000	.718	.006	.696
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47
EA	Pearson Correlation	.302*	.575**	.388**	.333*	.331*	.649**	.432**	.554**	.228	1	.437**	.485**	.616**	.328*
	Sig. (2-tailed)	.039	.000	.007	.022	.023	.000	.002	.000	.124	.	.002	.001	.000	.024
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47
AJ	Pearson Correlation	.496**	.473**	.126	.266	.272	.421**	.490**	.292*	.617**	.437**	1	.126	.500**	.139
	Sig. (2-tailed)	.000	.001	.400	.071	.064	.003	.000	.047	.000	.002	.	.399	.000	.351
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47
AD	Pearson Correlation	.087	.428**	.395**	.313*	.196	.516**	.499**	.328*	.054	.485**	.126	1	.422**	.187
	Sig. (2-tailed)	.561	.003	.006	.032	.187	.000	.000	.025	.718	.001	.399	.	.003	.209
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47
BF	Pearson Correlation	.459**	.501**	.185	.276	.415**	.665**	.578**	.411**	.394**	.616**	.500**	.422**	1	.464**
	Sig. (2-tailed)	.001	.000	.214	.060	.004	.000	.000	.004	.006	.000	.000	.003	.	.001
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47
IJ	Pearson Correlation	.302*	.182	-.038	.169	-.234	.391**	.504**	.273	.058	.328*	.139	.187	.464**	1
	Sig. (2-tailed)	.039	.221	.801	.255	.114	.007	.000	.063	.696	.024	.351	.209	.001	.
	N	47	47	47	47	47	47	47	47	47	47	47	47	47	47

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. SIDE_R = Left

APPENDIX – 6 STEPS FOR FINDING LENGTH OF ULNAE (N=110) FROM BONY MARKERS BY STEPWISE METHOD (MULTIVARIATE ANALYSIS)

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	15.609	1.481		10.540	.000	12.674	18.545
	CB	3.347	.499	.542	6.704	.000	2.358	4.337
2	(Constant)	13.032	1.567		8.319	.000	9.927	16.138
	CB	2.326	.548	.377	4.245	.000	1.240	3.412
	BF	1.838	.499	.327	3.683	.000	.849	2.827
3	(Constant)	11.785	1.567		7.522	.000	8.679	14.892
	CB	1.922	.545	.311	3.525	.001	.841	3.003
	BF	1.572	.489	.280	3.213	.002	.602	2.542
	GH	2.357	.784	.243	3.008	.003	.803	3.911
4	(Constant)	11.068	1.564		7.075	.000	7.966	14.170
	CB	1.627	.549	.263	2.965	.004	.539	2.714
	BF	1.371	.487	.244	2.817	.006	.406	2.336
	GH	1.975	.785	.203	2.517	.013	.419	3.531
	EH	.745	.317	.195	2.350	.021	.116	1.374
5	(Constant)	10.668	1.553		6.869	.000	7.588	13.747
	CB	1.171	.584	.190	2.006	.048	.013	2.328
	BF	1.325	.480	.236	2.761	.007	.373	2.277
	GH	1.614	.792	.166	2.037	.044	.043	3.185
	EH	.707	.313	.185	2.260	.026	.087	1.328
	AD	1.099	.533	.180	2.061	.042	.042	2.156

a. Dependent Variable: L

APPENDIX – 7 NAMES OF PERSONS FOR WHO X-RAYS WERE TAKEN

N0	FEMALE		MALE	
	Right	Left	Right	Left
1	Rukmani	Muriel	Rajendra	Sunil
2	Jaya	Ponmudi	Viswa	Prasannan
3	Poonjoli	Malliga	Padavi	Muniswamy
4	Thenmozhi	Sara	Selvaraj	Ruben
5	Manjula	Suganthy	Ratinum	
6	Muriel	Teekamma	Subran	
7	Ponmudi	Pappu	Palani	
8	Malliga	Mala	Samuel	
9	Sara	Suja	David	
10	Suganthy	Rani	Settu	
11	Teekamma	Anandhi	Sunil	
12	Pappu		Prasannan	
13	Mala		Muniswamy	
14	Suja		Ruben	
15	Rani			
16	Anandhi			

APPENDIX – 8 RADIOGRAPHIC MARKERS SHOWING MEASUREMENTS OF 15 INDIVIDUALS (15, RIGHT AND 15, LEFT).

No	Name	AD		BF		IJ		AB		L	
		Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt	Rt	Lt
1	Sunil	2.20	2.20	3.60	3.60	1.80	1.80	2.90	2.80	28.80	28.80
2	Muriel	1.90	1.90	3.10	3.10	1.50	1.50	2.40	2.40	28.50	28.40
3	Ponmudiyal	2.00	2.00	3.00	2.90	1.50	1.50	2.10	2.10	23.30	23.30
4	Malliga	1.70	1.70	3.00	3.00	1.50	1.30	2.10	2.10	23.10	22.30
5	Saraswathy	2.00	1.80	2.90	2.90	1.50	1.50	2.30	2.30	24.50	24.30
6	Suganthy	2.00	2.10	3.10	3.10	1.50	1.50	2.80	2.80	27.80	27.50
7	Prasannan	2.20	2.20	3.30	3.10	1.60	1.60	2.50	2.50	26.20	26.60
8	Munniswamy	2.20	2.20	3.30	3.10	1.60	1.60	2.30	2.30	27.70	27.60
9	Teekamma	2.10	2.10	3.10	3.20	1.60	1.60	2.10	2.10	25.70	25.50
10	Pappu	2.00	1.90	2.60	2.60	1.40	1.30	2.40	2.40	24.10	24.20
11	Malakody	2.10	2.00	2.90	2.90	1.40	1.50	2.20	2.20	25.40	24.30
12	Suja	2.30	2.30	3.40	2.80	1.80	1.50	2.10	2.00	23.90	23.80
13	Rani	1.90	1.70	2.60	2.60	1.50	1.50	2.00	2.20	23.60	23.60
14	Anandhi	2.50	2.30	3.40	2.80	1.80	1.50	2.20	2.10	23.90	23.80
15	Ruben	1.80	2.10	3.10	3.10	1.50	1.40	2.50	2.50	26.40	26.40

APPENDIX – 9 RADIOGRAPHIC MARKERS SHOWING MEASUREMENTS OF 30 INDIVIDUALS (15, RIGHT AND 15, LEFT)

NO	SIDE	NAME	AD	AB	IJ	BF	LENGTH	HEIGHT
1	RIGHT	RUKMANI	2	2.1	1.4	2.9	29.4	149
2	RIGHT	JAYA	2.3	2.4	1.9	3.4	28.4	163
3	RIGHT	RAJENDRA	2	3.4	1.9	3.4	28.2	165
4	RIGHT	MANJULA	2.2	1.4	1.5	3	23.3	141
5	RIGHT	VISWA	2	2.8	1.7	3.2	26.1	163
6	RIGHT	POONJOLI	1.6	2.3	1.4	3	22.1	142
7	RIGHT	PADAVI	2	2.5	1.7	3.1	26	155
8	RIGHT	THENMOZHI	1.8	2.5	1.6	3	25	151
9	RIGHT	SELVARAJ	2	2.8	1.8	3.3	28.1	160
10	RIGHT	RETHINUM	2.2	2.4	1.9	3.5	28.6	166
11	RIGHT	SUBRAN	2.1	2.7	2	3.6	30.2	163
12	RIGHT	PALANI	2.1	2.3	1.7	3.1	28.1	164
13	RIGHT	SAMUEL	2.1	2.4	2	3.4	29.3	170
14	RIGHT	DAVID	2.1	2.6	1.8	2.5	26.6	162
15	RIGHT	SETTU	2.5	2.6	2	3.1	29.1	165
16	LEFT	SUNIL	2.2	2.8	1.8	3.6	28	170
17	LEFT	MURIEL	1.9	2.4	1.5	3.1	28.5	164
18	LEFT	PONMUDI	2	2.1	1.5	2.9	23.3	145
19	LEFT	MALLIGA	1.7	2.1	1.3	3	23.1	142
20	LEFT	SARA	1.8	2.3	1.5	2.9	24.5	145
21	LEFT	SUGANTHY	2.1	2.8	1.5	3.1	27.8	164
22	LEFT	PRASANNAN	2.2	2.5	1.6	3.1	26.2	171
23	LEFT	MUNNISAMY	2.2	2.3	1.6	3.1	27.7	170
24	LEFT	TEEKAMMA	2.1	2.1	1.6	3.2	25.7	147
25	LEFT	PAPPU	1.9	2.4	1.3	2.6	24.1	144
26	LEFT	MALA	2	2.2	1.5	2.9	25.4	154
27	LEFT	SUJA	2.3	2	1.5	2.8	23.9	154
28	LEFT	RANI	1.7	2.2	1.5	2.6	23.6	144
29	LEFT	ANADHI	2.3	2.1	1.5	2.8	23.9	144
30	LEFT	RUBEN	2.1	2.5	1.4	3.1	26.4	154

APPENDIX – 10 DESCRIPTIVE STATISTICS OF RADIOGRAPHIC MARKERS AND HEIGHT OF 30 INDIVIDUALS.

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std.
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
AD	30	1.60	2.50	2.0500	.0364	.19957
AB	30	1.40	3.40	2.4000	.0641	.35135
IJ	30	1.30	2.00	1.6300	.0381	.20869
BF	30	2.50	3.60	3.0767	.0504	.27628
LENGTH	30	22.10	30.20	26.3533	.4141	2.26803
HEIGHT	30	141.00	171.00	156.3667	1.8323	10.03608
Valid N (listwise)	30					

APPENDIX – 11 PEARSON CORRELATION OF RADIOGRAPHIC MARKERS OF 30 INDIVIDUALS.

Correlations

		AD	AB	IJ	BF	LENGTH
AD	Pearson Correlation	1	.010	.501**	.291	.460*
	Sig. (2-tailed)	.	.959	.005	.119	.011
	N	30	30	30	30	30
AB	Pearson Correlation	.010	1	.517**	.440*	.530**
	Sig. (2-tailed)	.959	.	.003	.015	.003
	N	30	30	30	30	30
IJ	Pearson Correlation	.501**	.517**	1	.652**	.705**
	Sig. (2-tailed)	.005	.003	.	.000	.000
	N	30	30	30	30	30
BF	Pearson Correlation	.291	.440*	.652**	1	.635**
	Sig. (2-tailed)	.119	.015	.000	.	.000
	N	30	30	30	30	30
LENGTH	Pearson Correlation	.460*	.530**	.705**	.635**	1
	Sig. (2-tailed)	.011	.003	.000	.000	.
	N	30	30	30	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

ESTIMATION OF STATURE FROM PROXIMALBONY MARKERS OF ULNA-PICTURES

Fig. 1: Ulna

Fig. 2 Upper end of ulna

(Posterior view)

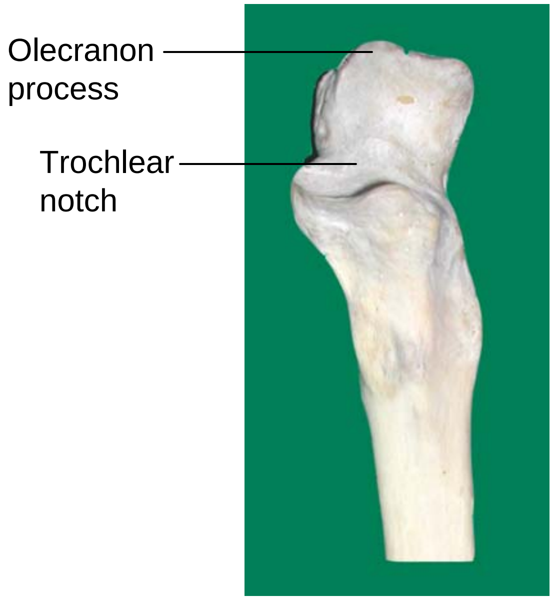

Fig. 3 Upper end of Ulna

(Anterior view)

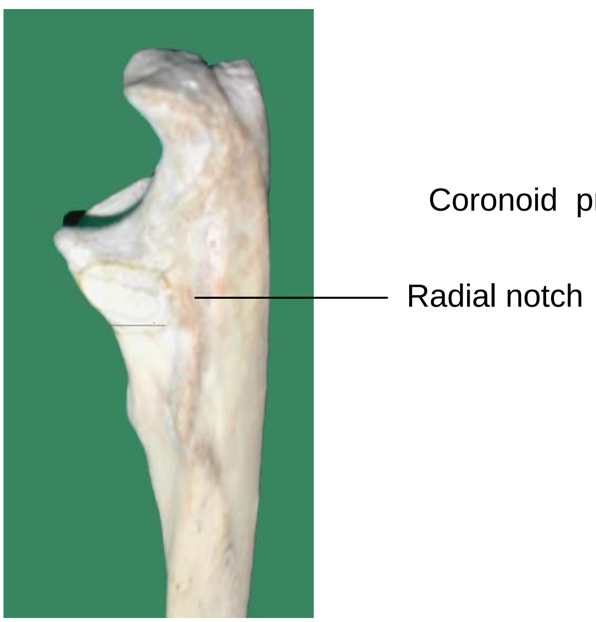

Fig. 4 Upper end of ulna

(Lateral view)

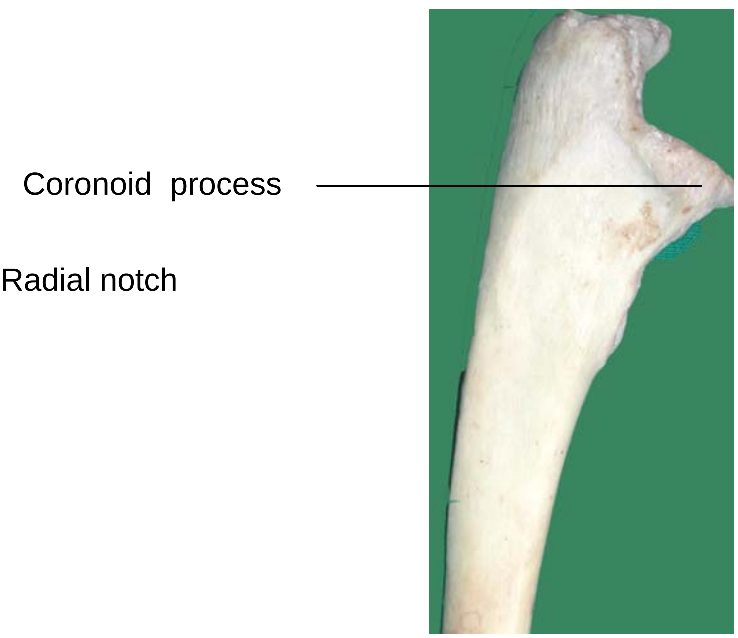

Fig. 5 Upper end of ulna

(medial view)

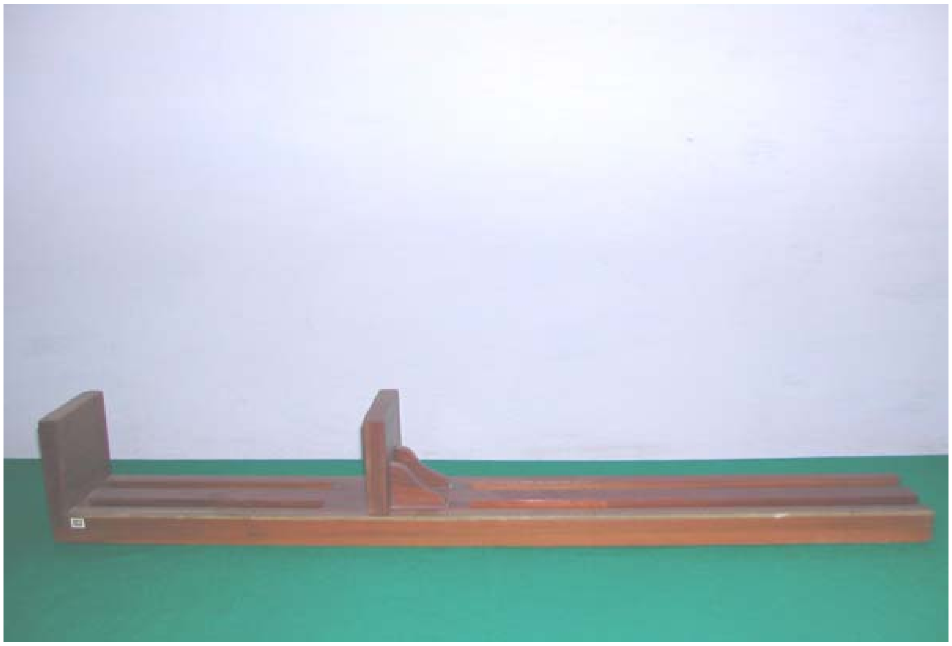

Fig. 6 Osteometric board

Fig. 7 Measurement of the length of the ulna using an osteometrIc board

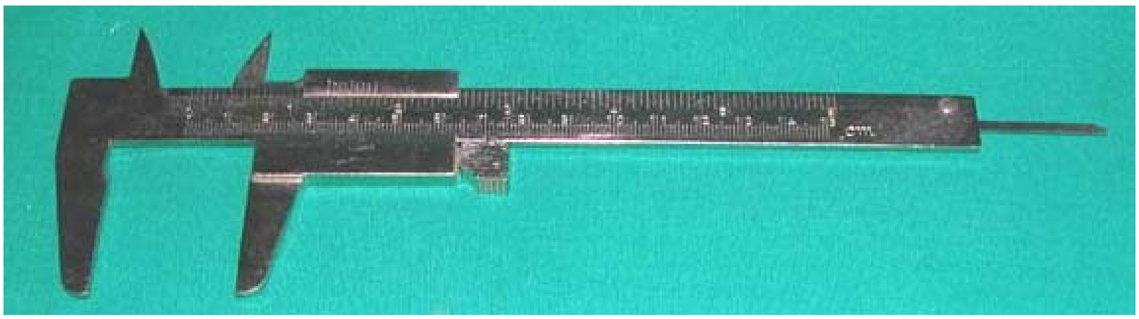

Fig. 8: Vernier caliper

Fig. 9: Showing measurement of EG

EG - Distance between the tip of the olecranon process posteriorly (E) and the anterior-most point on the radial notch distally (G)

Fig. 10: Measurement of EH with vernier caliper

EH - Distance between the tip of the olecranon process posteriorly (E) to the posterior-most point on the radial notch distally (H)

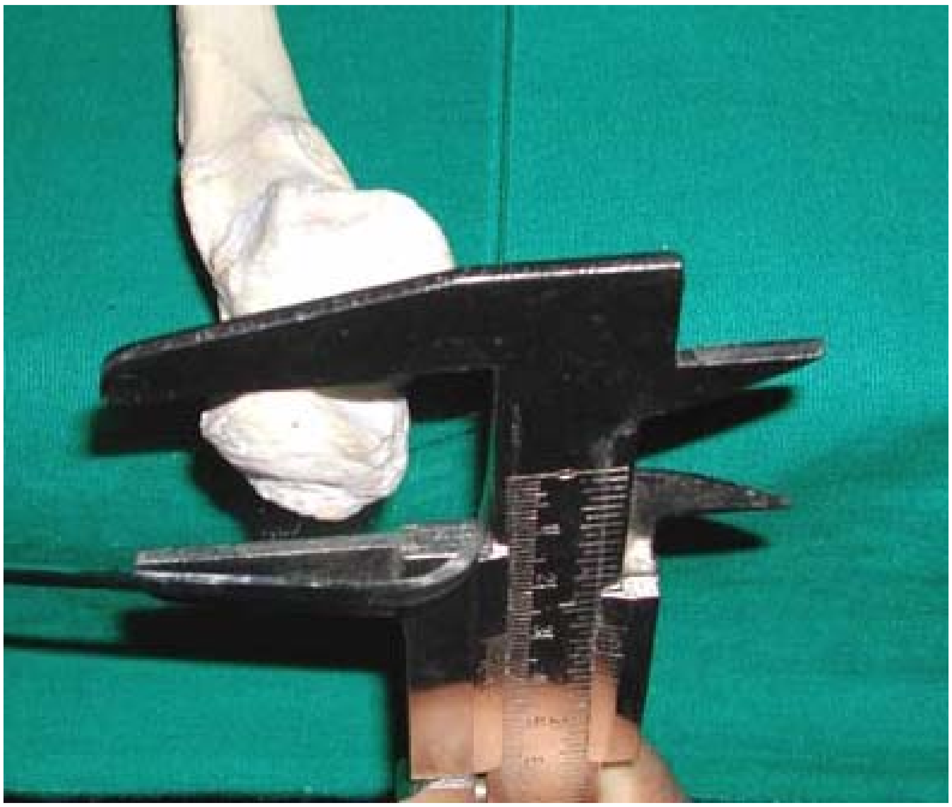

Fig. 11 : Measurement of IJ with vernier caliper and glass slide

IJ - Distance along the perpendicular to the long axis of the ulna from the posterior most point on the trochlear notch (I) to a point on posterior aspect of ulna

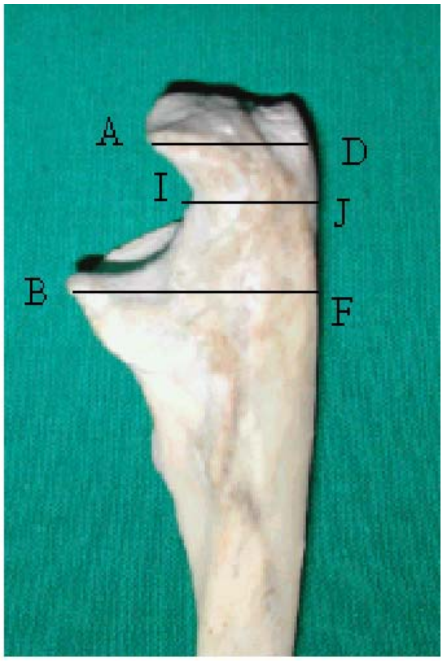

Fig. 12: Upper end of ulna showing IJ, BF and AD.

IJ - Distance along the perpendicular to the long axis of the ulna from the posterior most point on the trochlear notch (I) to a point on posterior aspect of ulna

BF- Distance along the perpendicular to the long axis of the ulna from the tip of coronoid process anteriorly (B) to a point on the posterior aspect of the ulna(F).

AD - Distance along the perpendicular to the long axis of the ulna from the anterior-most point on the olecranon process (A) to a point on the posterior aspect of the ulna (D)

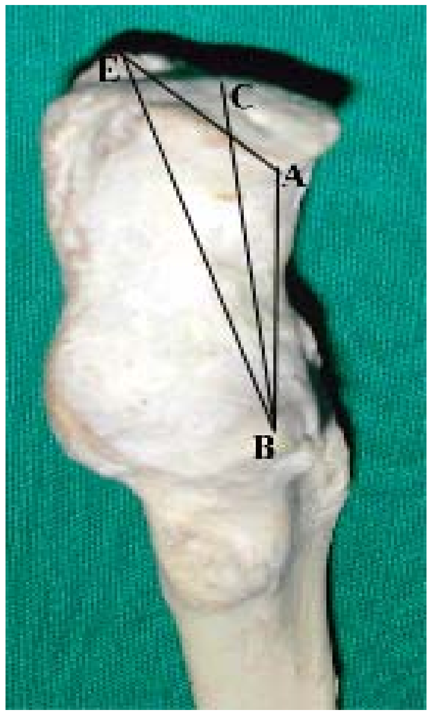

Fig. 13: Upper end of ulna showing AB, CB, EB and AE

AB - Distance between the anterior-most point on the trochlear notch superiorly (A) and inferiorly (B)

CB - Distance between the superior-most point on the olecranon(C) and anterior-most point on the coronoid process in the trochlear notch (B)

EB- Distance between the tip of the olecranon process posteriorly(E) to the anterior-most point on the trochlear notch inferiorly(B)

AE -Distance between the anterior-most point on the trochlear notch superiorly(A)to the tip of the olecranon process posteriorly (AE)

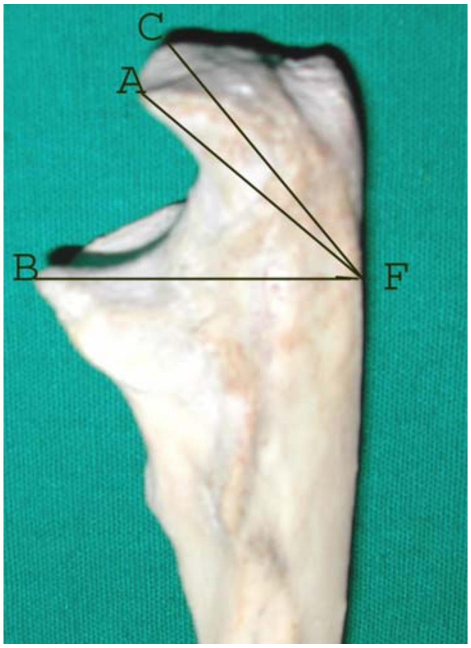

Fig. 14: Upper end of ulna showing AF and CF

AF- Distance between the anterior-most point on the trochlear notch superiorly (A) 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 (F)

CF - Distance between superior-most point on the olecranon (C) to a point on the posterior aspect of the ulna where the perpendicular to the long axis of the ulna passes through anterior most point of the coronoid process (F)

BF- Distance along the perpendicular to the long axis of the ulna from the tip of coronoid process anteriorly (B) to a point on the posterior aspect of the ulna(F).

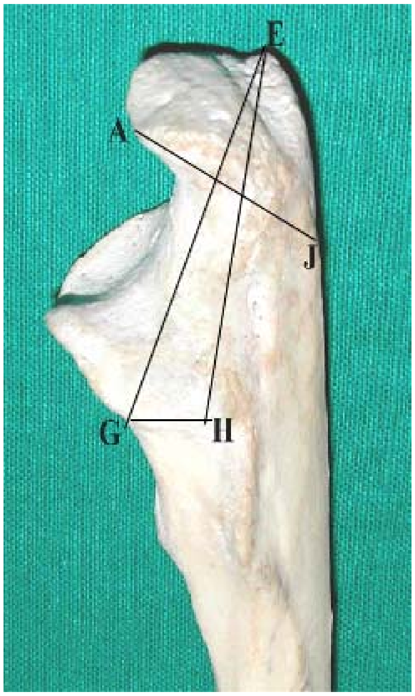

Fig. 15: Upper end of ulna showing GH, EG EH and AJ

GH - Distance between the anterior(G) and posterior ends of the radial notch(H)

EG - Distance between the tip of the olecranon process posteriorly (E) and the anterior-most point on the radial notch distally (G)

EH - Distance between the tip of the olecranon process posteriorly (E)to the posterior-most point on the radial notch distally (H)

AJ-Disance between the anterior-most point on the trochlear notch superiorly(A) 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 (J)

Fig. 16: Radiograph of ulna showing length (L), posterior most point of the trochlear notch I andJ - point on the posterior aspect of ulna where the perpendicular to the long axis of the ulna passes through point I

Fig. 17 Radiograph of ulna showing

A - anterior-most point on the trochlear notch superiorly

B - anterior-most point on the trochlear notch inferiorly

D - point on the posterior aspect of ulna where the perpendicular to the long axis of the ulna passes through point A.

F - point on the posterior aspect of the ulna where the perpendicular to the long axis of the ulna passes through point B