Original article:

Segmental morphometrics and their correlation with the whole length of long bones : a study on humerus of eastern India

[1]Dr. Moumita Chatterjee,[2] Dr. Ratnadeep Poddar* , [3]Dr. Iman Sinha,[4] Dr. Alipta Bhattacharya , [5]Prof. (Dr.) Asis Kumar Ghosal

[1]Ex PGT, Dept. of Anatomy, Institute of Post-Graduate Medical Education & Research (IPGMER), 244 AJC Bose Road, Kolkata 700020

[2]MBBS, MD(Anatomy) , Demonstrator, Department of Anatomy, Institute of Post-Graduate Medical Education & Research(IPGME&R), Kolkata, West Bengal, India

[3]MBBS, MD (Anatomy) , Assistant Professor, Department of Anatomy, Institute of Post-Graduate Medical Education & Research(IPGME&R), Kolkata, West Bengal, India

[4]MBBS, DO, MD(Anatomy) , Assistant Professor, Department of Anatomy, Institute of Post-Graduate Medical Education & Research(IPGME&R), Kolkata, West Bengal, India.

[5]MBBS, MS (Anatomy) , Professor & HOD , Department of Anatomy, Institute of Post-Graduate Medical Education & Research(IPGME&R), Kolkata, West Bengal, India

Corresponding author*

Abstract

Introduction: This study deals with the segmental morphometric study of human dry humerus and its correlation with whole length of the bone.

Materials & Methods: 100 dry humerus (48 right and 52 left sided) were analysed in this study for their whole lengths and individual specified segments' morphometry.

Results: Mean total length of the bone was 295.97±19.19mm. Five fragments (segments) were measured in the study. Their mean measurements are as follows: Length of segment H1 is 6.10±1.14 mm, length of segment H2 is 34.78±3.40 mm, length of segment H3 is 19.70±1.81mm, length of segment H4 is 16.74±2.46 mm and length of segment H5 is 34.85±2.57mm. A significant correlation was established between the whole length of the bone with segments H2 & H5.

Discussion: This study highlights the strong correlation between the whole length of humerus and its specific segments. This will be of immense help to the forensic and anthropometric experts in determining the stature of a person, even if the whole length of the bone is not available. Moreover, the prosthesis manufacturing units would be largely benefited due to availability of concerned data regarding shape and contour of the area of choice.

Key words: Humerus, Segmental Morphometrics, Sub-acromial clearance

Introduction:

The identity of a skeleton can be determined for medico-legal purposes by the morphometric studies. Morphometric analysis can be carried out on the long bones if cranium and pelvis are not available. In such cases measurements of femur, tibia, fibula for lower limb and humerus, radius, ulna for upper limbs are studied. At times the length of whole bone is not available. In such circumstances, certain procedures are undertaken to measure the length of various fragments of the bone and from this the length of whole bone can be calculated. Muscle attachments and articular surfaces are also taken into consideration for this purpose. Morphometric analysis of humerus in estimating stature of a given population is very useful in identifying unknown bodies, parts of bodies or skeletal remains[1]. Earlier some studies showed that measurements of right upper limb bones are greater than those of left side[2,3]. Moreover, studies have also suggested that there is great variation in different measurements of humerus among different races e.g. Caucasians, Portugese, Bulgarians, Spanish, Maya and Asian populations[1]. In Forensic anthropology, a method for estimating height based on the distances of segments of long bones is important. Steele and Mckern created a method based on the proportionality between determined distances among fixed points of bones and their total length[4]. Recent studies show that a person's stature is an extremely variable biological parameter. Moreover, diurnal variation of stature has been reported from person to person and among different populations[5-8]. Steyen et al. developed an osteometric sex determination technique using humerus[9]. Mall G et al. attempted to estimate stature and determine sex from some accessible measurements of bones which were collected by removing the soft tissues cartilages, ligaments mechanically[10]. Wright et al. conducted a study to report on new standards for estimating long bone length from incomplete bones for use in forensic and archaeological contexts in Central America[11]. The measurements they used closely followed those defined by Steele[4], but they add several new landmarks. Esomonu and colleagues conducted a study in Nigerian population to estimate the total length of humerus from the length of the fragments of humerus using regression equation[12]. Similar studies were also conducted in India referring to stature and humeral length estimation from its fragments or segments[13-17]. Thus, it is evident, forensic experts would have to rely, sometimes, on parts of bones as the whole bone might not be available always. The present study is based on correlation of actual humeral length with the measurements of specified segments or fragments of the same. This might be extrapolated to estimation of actual stature of an individual from the fragments of humerus bone, in future.

Aims & Objectives:

Aims and objectives of the index study were:

a) To study the total length and lengths of various segments of the humerus.

b) To predict the length of humerus from its segments.

c) To compare the present findings with the data of previous studies.

Materials & Methods:

The study was conducted using 100 fully ossified and processed dry specimen of human humerus bone, irrespective of their age and genders. Unossified bones & bones with diseases and injuries were excluded from the present study. Measurements were taken with the help of osteometric board and electronic digital calliper. Lengths and breadths were measured in millimetres. Total length of humerus was recorded with help of osteometric board, while the segmental measurements were done using electronic callipers. The following parameters were described for analysis in this study :

1. Length of the bone: It is the direct distance from the most superior point on the head of the humerus to the most inferior point on the trochlea.

2. Length of five segments of humerus was measured on the basis of six bony points. These points and concerned segments are depicted in the Figures 1, 2 & 3.

With the lengths of each segment and the whole length of the bone available, a predictive equation has been tried to be formulated in the index study. Data was summarized by routine descriptive statistics, namely range, mean with standard deviation, median with interquartile range and 95%

confidence interval of the mean. All numerical variables analyzed were normally distributed by Kolmogorov-Smirnoff goodness-of-fit test. Comparison between left and right cohorts was done by Student's independent samples t test. Strength of association between total humerus length and length of individual fragments was quantified by Pearson's correlation coefficient *r*. Scatter plots have been presented for moderate to good correlations. Simple linear regression was applied to generate a predictive equation for humerus length from length of an individual fragment. P value < 0.05 was considered statistically significant. Statistica version 6 [Tulsa, Oklahoma: StatSoft Inc., 2001] and MedCalc version 11.6 [Mariakerke, Belgium: MedCalc Software 2011] software were used for statistical analysis.

Results and Analysis:

100 dry humerus bones (48 Right and 52 Left) were analysed in the present study. Mean total length of the bone was 295.97±19.19mm. Five fragments (segments) were measured in the study. The measurements are as follows: Length of segment H1 is 6.10±1.14 mm, length of segment H2 is 34.78±3.40 mm, length of segment H3 is 19.70±1.81mm, length of segment H4 is 16.74±2.46 mm and length of segment H5 is 34.85±2.57mm. Table 1 shows descriptive statistics of various fragments of humerus.

Comparison between left and right cohorts was done by Student's independent samples t test. Right and left humerus was compared for all the descriptive variables. No significant difference was observed between humeri of two sides with respect to the concerned variables, as shown in Table 2.

Strength of association between total humerus length and length of individual fragments was quantified by Pearson's correlation coefficient *r*. Significant correlation (P < 0.01) was observed between total length of humerus and length of segment H2, length of segment H5. Table 3 shows the correlation matrix between total length of humerus and individual segment lengths. Simple linear regression was applied to generate a predictive equation for humerus length from length of an individual fragment. P value < 0.05 was considered statistically significant. This is shown in Tables 4 and 5. To confirm the strength of association scattered plot diagrams were also computed as evident in Figures 4 and 5, for segment H2 and H5 respectively.

Discussion:

Morphometric measurements of long bones play a vital role in estimation of stature of an individual. Humerus is the longest bone of the upper limb and its morphometric measurements can be useful for descriptive and comparative purpose. Many studies have been conducted in India and abroad focussing on morphometric measurements of humerus and in turn predicted the whole length of humerus from its segments[1,2,18]. Some studies also revealed the sexual dimorphism in different measurements[19].

From Table 6 it is evident that measurements of all humerus segments and whole length of the bone as found in the study by Akman et al. in Caucasian population were higher than that found in the index study[1]. However, the measurements of the index study were in keeping with other Indian studies with lesser values for certain variables. As there is no other study from Eastern India it was difficult to draw any conclusion regarding this lower value in the index study. Highest point on the articular surface is 6 to 8 mm higher than the highest point of the greater tubercle as described in some studies[1]. This relationship determines the degree of subacromial clearance when the arm is elevated. This is also important for assessment of isolated greater tuberosity fracture. This measurement was 6.5±1.6 mm for right side and 6.6±1.3 mm for left side in one of the previous studies[1]. In index study this measurement (H1) showed a value of 6.30± 1.1 mm for right side and 5.91±1.14 mm for left side. This shows population from Eastern India has comparatively lesser subacromial clearance. One previous study showed the distance between proximal margin of olecranon fossa and distal most point on trochlea was 40.6±3.3 mm for right side and 39.7±3.4 mm for left side[1]. The said measurement (H5) in the index study was 35.02±2.80 mm for right side and 34.68±2.35 mm for left side. In a study conducted by Rai and Chawla the mean values of the above mentioned parameters were measured for both sides[2]. The values were consistent with the present study as shown in Table 6. The whole length of humerus was 302±21.4 mm for right side and 297.5±21.1 mm for left side whereas in index study these values were 299.29 ±19.86 mm for right side 292.90 ±18.19 mm for left side. Both the values were higher compared to the present study. Mean values of all the segments in the index study were lesser in comparison to the study by Rai et al. except for the length of fifth segment (H5) [2]. Rai et al. recorded it to be 32.6±3.5 mm and 34.5±3.6mm for right and left side respectively whereas in present study the values were 35.02±2.80 mm for right side and 34.68±2.35 mm for left side[2]. This variation of length in segment H5 can help in individualisation of planning of orthopedic reconstruction of distal humerus in this section of population. Somesh et al. conducted a similar study[18]. They performed the study with 100 adult dry humerus (49 right and 51 left). Sex determination was not done. They measured five segments and the whole length of humerus. The authors established the relation of humeral length with the length of its segments by Pearson's correlation coefficient formula. They observed that the humeral length could be best determined by the length of the second and fifth segments, which corroborated with the present study. They proposed simple linear regression formulae for all five segments to calculate the whole humerus length (Table 7). However, Somesh et al. could not compare the results between right and left side as the bones were not from the same individual[18].

Laxmikantha et al. conducted a study with the length of six segments and whole length of humerus[3]. They observed that whole length of the humerus could be determined reliably by the length of the third, fourth and fifth segments. Both the index study and the study by Esomonu et al. derived the regression equation by the distance from the most proximal point on margin of olecranon fossa to the most distal point of trochlea (H5)[12]. So this segment was important for estimation of whole length. Singhal et al. studied 150 dry adult unpaired humeri of both sides and of unknown sex from South India[15]. The humeri were divided into eight segments using salient bony points and muscular markings. A study by Mohanty et al. estimated the length of humeri from measurements of their segments (Five) in South Indian population[31]. In both the studies there were significant correlation among the segments and whole length of the bone.

Conclusion:

When whole length of the bone is not available, the length of different segments of a long bone can predict the length by regression equation. Length of different segments could be helpful to determine the whole length by regression analysis. Segmental length could also be useful for many reconstructive procedures in orthopaedic surgeries as in proximal humeral fracture, olecranon fracture, intra medullary nailing etc. Complex fractures can cause problems in reconstruction and lead to neurovascular damage to the distal humerus. Various implants contoured for this specific region are available for fractures in distal humerus. Measurements of the segments of the distal humerus are important. Moreover, it is important in forensic investigations and in archaeological studies particularly when the fragmentary portions are examined.

Table 1: Descriptive statistics of various fragments of humerus

Variables		**Minimum (in mm)**	**Maximum (in mm)**	**Mean (S.D.)**
Length of segment H1	Whole Sample (N=100)	3.24	9.62	6.10 (1.14)
	Right (N=48)	3.99	9.62	6.30 (1.10)
	Left (N=52)	3.24	8.36	5.91 (1.14)
Length of segment H2	Whole Sample (N=100)	26.33	43.12	34.78 (3.40)
	Right (N=48)	26.33	43.12	35.23 (3.32)
	Left (N=52)	28.03	41.25	34.37 (3.45)
Length of segment H3	Whole Sample (N=100)	15.92	25.53	19.70 (1.81)
	Right (N=48)	15.92	23.97	19.64 (1.76)
	Left (N=52)	16.14	25.53	19.75 (1.88)
Length of segment H4	Whole Sample (N=100)	12.46	24.24	16.74 (2.46)
	Right (N=48)	12.46	24.24	16.60 (2.26)
	Left (N=52)	13.36	24.21	16.88 (2.64)
Length of segment H5	Whole Sample (N=100)	29.21	41.41	34.85 (2.57)
	Right (N=48)	29.35	41.41	35.02 (2.80)
	Left (N=52)	29.21	39.10	34.68 (2.35)

Table 2: Comparison of numerical variables between right and left cohort

	Mean(**Rt.**) in mm	Mean(**Lt.**)in mm	t-value	P (significance)
Length of segment H1	6.30	5.91	1.713	0.90
Length of segment H2	35.23	34.37	1.265	0.209
Length of segment H3	19.64	19.75	-0.310	0.757
Length of segment H4	16.60	16.88	-0.573	0.568
Length of segment H5	35.02	34.68	0.658	0.512

Table 3: Correlation matrix between total length of humerus and individual segment lengths

	Tot. Length	**Length seg. H1**	**Length seg. H2**	**Length seg. H3**	**Length seg. H4**	**Length seg. H5**
Maximum length of the bone	-	0.242	**0.626****	0.143	0.062	**0.395****
Length of segment H1	0.242	-	**0.257****	0.081	**0.323****	**0.263****
Length of segment H2	**0.626****	**0.257****	-	0.055	0.150	**0.352****
Length of segment H3	0.143	0.081	0.055	-	0.162	**0.536****
Length of segment H4	0.062	**0.323****	0.150	0.162	-	**0.586****
Length of segment H5	**0.395****	**0.263****	**0.352****	**0.536****	**0.586****	-

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

Table 4: Predicting humerus length from length of segment H2 - Linear Regression[a]

Independent variable	**R Square**	**Adjusted R Square**	**Residual standard deviation**
Length of segment H2	0.392	0.386	15.03657

a. Dependent variable – Maximum length of the bone

Regression Equation

$y = 173.3113 + 3.5254\ x$					
Parameter	Coefficient	Std. Error	95% CI	T	P
Intercept	173.3113	15.5095	142.5332 to 204.0895	11.1745	<0.0001
Slope	3.5254	0.4437	2.6449 to 4.4058	7.9461	<0.0001

Table 5: Predicting humerus length from length of segment H5 – Linear Regression[a]

Independent variable	**R Square**	**Adjusted R Square**	**Residual standard deviation**
Length of segment H5	0.156	0.146	17.71479

a. Dependent variable – Maximum length of the bone

Regression Equation

$y = 193.2189 + 2.9482\ x$					
Parameter	Coefficient	Std. Error	95% CI	T	P
Intercept	193.2189	24.1719	145.2506 to 241.1871	7.9935	<0.0001
Slope	2.9482	0.6917	1.5756 to 4.3208	4.2623	<0.0001

Table 6: Comparison of descriptive data between index study and three other studies conducted by other researchers

Variables	Sidedness	Index Study	Study by Akman et al. [1]	Study by Rai et al. [2]	Study by Somesh et al. [18]
Length (in mm)	Right	299.29 ±19.86	307.1±20.08	302±21.4	309.6± 20.6
	Left	292.90 ±18.19	304.8±18.9	297.5±21.1	299.6± 22.5
H_1 (in mm)	Right	6.30 ±1.10	6.5±1.6	6.4 ± 1.3	5.9± 1.1
	Left	5.91 ±1.14	6.6±1.3	6.5± 1.3	5.8± 1.5
H_2 (in mm)	Right	35.23 ±3.32	41.0±5.1	39.3± 5.4	37.1± 4.8
	Left	34.37 ±3.45	40.9±3.9	39.2 ± 4.8	37.7± 4.4
H_3 (in mm)	Right	19.64 ±1.76	24.2±2.0	27.4± 2.4	20.1± 3.4
	Left	19.75 ±1.88	23.9±2.6	27.5± 2.6	19.0± 2.9
H_4 (in mm)	Right	16.60 ±2.26	20.0±2.2	26.1± 2.9	17.2± 4.7
	Left	16.88 ±2.64	19.7±2.5	22.1± 2.3	16.8± 2.2
H_5 (in mm)	Right	35.02 ±2.80	40.6±3.3	34.5± 3.6	37.2± 4.7
	Left	34.68 ±2.35	39.7±3.4	32.6± 3.5	35.7± 4.3

www.ijbamr.com P ISSN: 2250-284X , E ISSN : 2250-2858

Table 7: Linear regression equation to calculate whole length of humerus from its fragments [18]

Left side	**Right side**
HL=271.46+4.83 (H_1)	HL=289.8+3.34(H_1)
HL=226.43+1.94 (H_2)	HL=210.46+2.67 (H_2)
HL=261.02+2.02(H_3)	HL=305.57+0.20 (H_3)
HL=273.61+1.3(H_4)	HL=269.56+2.3 (H_4)
HL=252.91+1.3(H_5)	HL=22.00+2.02(H_5)

Figure 1 : Segments of Humerus on basis of fixed reference points

A-B: The distance between the most proximal point of the articular segment of the humeral head to the most proximal point of the greater tuberosity (H1).

A-C: The distance between the most proximal point of the articular segment of head and anatomical neck (H2).

D-E: The distance between the most distal point and the most proximal point along the edge of the olecranon fossa. (H3).

E-F: The distance between the most distal point of the olecranon fossa and the most distal point of trochlea (H4).

D-F: The distance between the most proximal point on the margin of olecranon fossa and the most distal point of the trochlea (H5).

Figure 2 : Measuring whole length with Osteometric Board

Figure 3: Measuring one of the segments with digital callipers

Figure 4: Scatterplot showing the relation between maximum length of the bone and length of segment H2

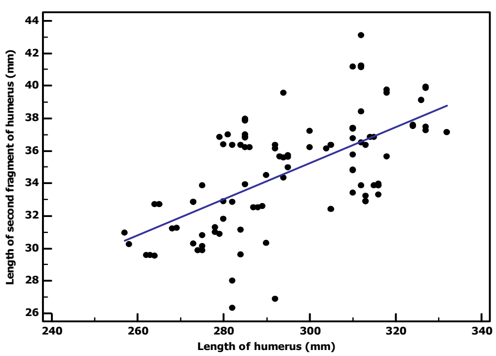
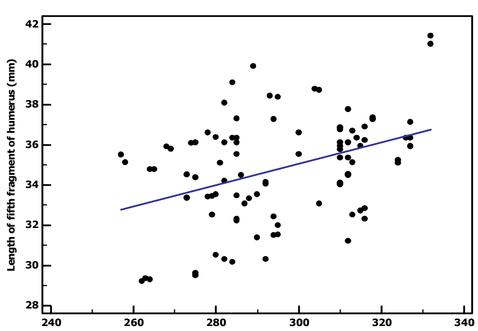


Figure 5: Scatterplot showing the relation between maximum length of the bone and length of segment H5



References:

1. Akman SD, Karakas P, Bozkir G. The morphometric measurements of humerus segments. Turk J Med Sci 2006;36:81-88
2. Rai R, Chawla M. Morphometry of adult humerus bone in Moradabad region. Int J Biomed Adv Res 2014;5:163-165
3. Laxmikantha BM, Kulkarni R. Estimation of total length of humerus from its fragments in South Indian population. Int J Anat Res 2014;2:213-220
4. Steele DG, McKern TW. A method for assessment of maximum long bone length and living stature from fragmentary long bones. Am J Phys Anthropol 1969;31:215- 228
5. Brothwell DR. Digging up bones: the excavation, treatment and study of human skeletal remains. Ithaca, NY: Cornell University Press; 1981 .p. 113- 247
6. Galloway MA. Estimating actual height in the older individual. J Forensic Sci 1988;33:126-136
7. Giles E. Corrections for age in estimating older adults stature from long bones. J Forensic Sci 1991;36:898-901
8. Hertzog KP, Garn SM, Hempy HO. Partitioning the effects of secular trend and aging on adult stature. Am J Phys Anthropol 1969;31:111-115.
9. Steyn M, Işcan MY. Osteometric variation in the humerus: sexual dimorphism in South Africans. Forensic Sci Int 1999;106:77-85
10. Mall G, Hubig M, Buttner. A sex determination and estimation of stature from the long bones of the arm. Forensic Sci Int 2001;117:23-30
11. Wright LE, Vásquez MA. Estimating the length of incomplete long bones: forensic standards from Guatemala. Am J Phys Anthropol 2003;120:233
12. Esomonu UG, Taura MG, Ibeabuchi NM, Modibbo MH. Regression equation for estimation of length of humerus from its mophometry in a Nigerian population. Nig Q J Hosp Med 2013; 23:135-138
13. Krishan K, Kanchan T, DiMaggio JA. A study of limb asymmetry and its effect on estimation of stature in forensic case work. Forensic Sci Int 2010;200:181
14. Udhaya K, Sarala Devi KV, Sridhar J. Regression equation for estimation of length of humerus from its segments: A South Indian Population Study. J Clin Diagn Res 2011;5:783-786
15. Singhal S, Rao V. Estimation of total length of humerus from its segments. Med Sci Law 2011;51:18-20
16. Mohanty S, Sahu G, Das S. Estimation of length of humerus from its fragmentary portions. J Forensic Leg Med 2012;19:316-320
17. Desai SD, Shaik HS. A morphometric study of humerus segments. J Pharm Sci Res 2012;4:1943-1945
18. Somesh MS, Prabhu LV, Shilpa K, Pai MM, Krishnamurthy A, Murlimanju B. Morphmetric study of the humerus segments in Indian Population. Int J Morphol 2011;9:1174-1180
19. Lokanadham S, Khaleel N, Raj PA. Morphometric analysis of humerus bone in Indian population. Sch J App Med Sci 2013;1:288-290

www.ijbamr.com P ISSN: 2250-284X , E ISSN : 2250-2858