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Estimation of humeral length from its fragmentary dimensions

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ABSTRACT

The determination of sex and the estimation of stature from bones play an important role in identifying unknown bodies, parts of bodies or skeletal remains. Broken bones recovered from the scene of crime were discarded prior to 1935 can be utilized for reconstructing the length of bone because there exists a definite relationship between bone segment with its length and subsequently to stature. The present study aims at formulating means of reconstruction of humeral length from fragmentary measurements pertaining to multiple dimensions of humerus. A total of 225 humeri belonging to 120 right and 105 left sides were measured using standard osteometric techniques for 14 linear, transverse, sagittal and circumferential measurements along with maximum length. Data was subjected to relevant statistical analysis for formulating means of bone length reconstruction. Analysis of data reveals significant bilateral differences at p<.05 level. Linear and multilinear regression formulae were derived for both sides. The highest correlation with humeral length is shown by Transverse diameter of head for right side and upper epiphyseal breadth for left side.

Keywords: Osteometric measurements, humeral length, fragmentary measurements, correlation, multilinear regression.

INTRODUCTION:

Stature is one of the essential parameters in the establishment of identity of an individual. The problems of identification through skeletal remains become much more cumbersome when the skeletal material is recovered in fragmentary form. Such broken bones could not attract the attention of investigating official at the initial stage but subsequently scientists developed technique to use the broken fragments of the bones to reconstruct respective bone length, which could eventually be used to reconstruct the stature. Muller (1935) provided a method for reconstruction of bone length from fragmentary measures of humerus, radius and tibia and Patel et al. (1964) formulate regression equations for estimation of height on tibial length. Chandra et al. (1966) carried out a study on the proportion of various segments of femur to its total length. Steele and McKern (1969) and Steele (1970) determined segments of long bones such as femur, tibia, and humerus and formulate sex specific regression equations. Rother et al. (1980) established formulas for the determination of stature from individual fragments of femur and then Mysorekar et al. (1980, 1982) conducted study on tibia, femur and radius.

Chandra and Nath (1985) reconstruct femur length and humeral length from their fragments. Badkur (1985) calculated regression formulae for both the sexes and for all six bones. And also Badkur and Nath (1989, 1990a, 1990b, 1993, 1995) computed certain linear and multilinear regression formulae for reconstruction of humerus, radius, ulnar and femur length. Simmons et.al (1990) has revised the technique for estimation of stature from fragmentary femora by incorporating eight linear and transverse measurements.

Major work on bone fragments has been done by Gupta and Nath (1996 to 2001). Datta and Nath (2001, 2002) formulate certain linear equations for estimation of fibular and humeral length. Wright and Vásquez (2003) derived the equations by regressing bone segment length on bone length of Femur, humerus, tibia, and fibula. Chibba and Bidmos (2007) and Bidmos (2008, 2009) derived equations for estimation of stature. Somesh et.al (2011) carried out morphometric study of the humerus segments in Indian population and formulates simple linear regressions to correlate five different segments with the total length of humerus. Recent work has been done by Chandran and Kumar (2012) for reconstruction of femur length from its fragments in South Indian males and Mohanty, Sahu and Das (2012) for estimation of humeral length from its fragmentary portions.

MATERIALS AND METHODS:

Data for the present study comprises of 225 humeri pertaining to 120 right side and 105 left side. Each bone was measured for 15 linear, transverse, sagittal and circumferential fragmentary dimensions in accordance with the standard osteometric measurement techniques recommended by Martin and Saller (1959) and Bass (1971). Data was subjected to relevant statistical analysis to formulate linear and multilinear regression equations to reconstruct humeral length from its fragmentary measurements.

List of measurements used for estimating humeral length from its fragments (Fig 1):

1. **Maximum length (ML)**: It measures the straight distance between the highest point on the head and the deepest point on the trochlea.(a-p)
   Instrument used: Osteometric board
1. **Upper epiphyseal breadth (UEB)**: It is obtained as a distance between the medial most point on the articular surface of the head and the lateral most point on the greater tubercle.(b-c)
   Instrument used: Vernier caliper
2. **Lower epiphyseal breadth (LEB**): It is obtained as a distance between the most lateral point on the lateral epicondyle and the tip of medial condyle.(k-l)
   Instrument used: Vernier caliper
3. **Transverse diameter at the middle of the shaft (TDMS)**: It measures the distance between the medial and lateral margins of the humeral shaft at the middle.(g-h)
   Instrument used: Vernier caliper

4. **Sagittal diameter at the middle of the shaft (SDMS)**: It measures the anterior-posterior thickness of the humeral shaft at middle where the transverse diameter has been taken.(g-h)
   Instrument used: Vernier caliper
5. **Mid shaft circumference (MSC)**: It measures the circumference of the humeral shaft at the middle where the transverse and sagittal diameters have been taken.(g-h)
   Instrument used: Flexible tape
6. **Transverse diameter at the upper half of the shaft (TDUS)**: It measures the distance between the medial and lateral margins at the middle of upper half of the humeral shaft.(e-f)
   Instrument used: Vernier caliper
7. **Sagittal diameter at the upper half of the shaft (SDUS)**: It measures the anterior-posterior thickness of the humeral shaft at the middle of the upper half of the shaft where the transverse diameter has been taken.(e-f)
   Instrument used: Vernier caliper
8. **Upper shaft circumference (USC)**: It measures the circumference of humeral shaft at the middle of the upper half of shaft where the transverse and sagittal diameters have been taken.(e-f)
   Instrument used: Flexible tape
9. **Transverse diameter at the lower half of shaft (TDLS)**: It measures the distance between the medial and lateral margins of the humeral shaft at the middle of the lower half of shaft.(i-j)
   Instrument used: Vernier caliper.
10. **Sagittal diameter at the lower half of the shaft (SDLS)**: It measures the anterior-posterior thickness of the humeral shaft at the middle of the lower half of shaft where the transverse diameter has been taken.(i-j)
    Instrument used: Vernier caliper
11. **Lower shaft circumference (LSC):** It measures the circumference of the humeral shaft at the middle of the lower half of shaft where transverse and sagittal diameters have been taken.(i-j)
    Instrument used: Flexible tape
12. **Transverse diameter of the head (TDH):** It measures the horizontal distance between the lateral most points on the articular margin of the head.
    Instrument used: Vernier caliper
13. **Vertical diameter of the head (VDH)**: It measures the distance between the highest and the lowest point on the articular margin of the head taken at right angle to the transverse diameter.(q-d)
    Instrument used: Vernier caliper
14. **Circumference of the head (CH)**: It measures the circumference of the humeral head along its articular surface.(q-d-q)
    Instrument used: Flexible tape

HUMERUS

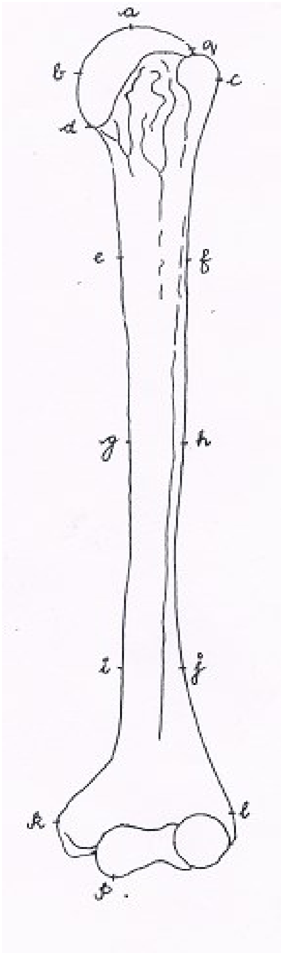

Fig. I

RESULTS:

In order to asses bilateral variations in the different dimensions the data have been subjected to t-test. Table-1 presents the mean values of all the fifteen measurements obtained on right and left sides of humerus along with the values of‘t’. It is apparent from table-1 that the right humeri have greater dimensions than the left ones for all measurements expect for TDH where the left side exhibits greater dimension and in case of TDLS dimensions are same for both the sides. These variations observed in case of right and left side bone dimensions when

Table 1. Comparison of different measurements of left and right sides of humeri

Humerus	Right side			Left side			Value of
Measurements	Mean	S.D	S.E.$\overline{x}$	Mean	S.D	S.E.$\overline{x}$	‘t’
1. ML	30.84	1.78	0.16	30.79	1.73	0.17	0.21
2. UEB	4.63	0.29	0.03	4.61	0.27	0.02	0.48
3. LEB	5.82	0.43	0.04	5.79	0.44	0.04	0.53
4. TDMS	1.87	0.19	0.02	1.80	0.23	0.02	2.50*
5. SDMS	2.01	0.18	0.02	1.94	0.20	0.02	2.50*
6. MSC	5.94	0.48	0.04	5.79	0.50	0.05	2.34*
7. TDUS	1.96	0.19	0.02	1.90	0.18	0.02	2.14*
8. SDUS	2.08	0.21	0.02	2.03	0.19	0.02	1.78
9. USC	6.37	0.55	0.05	6.21	0.59	0.06	2.05*
10. TDLS	1.93	0.21	0.02	1.93	0.19	0.02	0.00
11. SDLS	1.74	0.18	0.02	1.72	0.15	0.01	0.90
12. LSC	5.76	0.43	0.04	5.68	0.47	0.05	1.25
13. TDH	3.96	0.26	0.02	3.97	0.24	0.02	0.36
14. VDH	4.26	0.33	0.03	4.25	0.29	0.03	0.24
15. CH	13.03	0.86	0.08	13.02	0.78	0.08	0.08

*Significant at the $p < .05$ level

subjected to t-test reveals significant bilateral differences at $p < .05$ level of significance for MSC, TDUS, SDUS, and TDLS and for other measurements t-test does not reveal any significant bilateral differences at $p < .05$ level of significance.

Reconstruction of humeral length from its fragmentary measurements

On subjecting the data to regression analysis, different linear and multilinear regression equations have been formulated for the prediction of humeral length from its fragments. Table-2 exhibits 14 regression equations each for right and left side based on linear, transverse, sagittal and circumferential measurements. The correlation coefficient(r) ranges between .653 and .319 for right side and .540 and .193 for left side. The relationship of these fragmentary measurements with humeral length is variable for both the sides for example Upper epiphyseal breadth (UEB) exhibits sufficiently high correlation for right side ($r = .643$) as against left side ($r = .540$).

Table-2: Linear regression equations for reconstruction of humeral length from fragmentary dimensions of right and left side humerus.

Humerus	Regression Equation	SEE	Correlation Coefficient(r)
Right side			
1.	HL=13.123+3.822(UEB)	±1.948	0.643
2.	HL=16.049+2.539(LEB)	±1.711	0.624
3.	HL=25.305+2.955(TDMS)	±1.520	0.319
4.	HL= 24.098+3.347(SDMS)	±1.683	0.347
5.	HL=21.670+1.542(MSC)	±1.811	0.423
6.	HL=23.138+3.924(TDUS)	±1.481	0.433
7.	HL=24.451+3.061(SDUS)	±1.494	0.368
8.	HL=19.916+1.713(USC)	±1.598	0.534
9.	HL=25.719+2.653(TDLS)	±1.379	0.325
10.	HL=24.007+3.927(SDLS	±1.464	0.396
11.	HL=19.205+2.018(LSC)	±1.876	0.497
12.	HL=13.530+4.368(TDH)	±1.850	0.653
13.	HL=17.970+3.016(VDH)	±1.702	0.572
14.	HL=13.503+1.330(CH)	±1.877	0.648
Left side			
1.	HL=14.732+3.485(UEB)	±2.482	0.540
2.	HL=19.724+1.912(LEB)	±2.000	0.482
3.	HL=27.528+1.815(TDMS)	±1.300	0.243
4.	HL= 26.246+2.339(SDMS)	±1.609	0.271
5.	HL=25.509+0.913(MSC)	±1.888	0.268
6.	HL=27.245+1.863(TDUS)	±1.799	0.193
7.	HL=25.117+2.802(SDUS)	±1.700	0.315
8.	HL=26.190+0.742(USC)	±1.744	0.254
9.	HL=27.374+1.777(TDLS)	±1.632	0.204
10.	HL=25.165+3.281(SDLS)	±1.842	0.291
11.	HL=24.714+1.070(LSC)	±1.958	0.295
12.	HL=16.782+3.527(TDH)	±2.365	0.507
13.	HL=18.708+2.847(VDH)	±2.178	0.482
14.	HL=16.054+1.132(CH)	±2.468	0.510

HL = Humeral length

Table-3 presents three multilinear regression equations each for right and left sides incorporating 6 out of14 fragmentary measurements. UEB, LEB, TDH, and VDH works out to be the best predictor of humeral length for both sides as the value of multiple correlation enhances to a maximum of .716 for right side and .575 for left side, in contrast to the values of linear correlation (table-2)

Table-3: Multilinear regression equations for reconstruction of humeral length from fragmentary dimensions of right and left side humerus.

Multilinear Regression Equations	SEE	Multiple correlation coefficient(r)
Right side		
1. 9.935+1.774(UEB)+1.097(LEB)+2.338(TDH)+0.742(VDH)	±1.930	0.716
2. 11.362+2.211(UEB)+1.300(LEB)+0.260(USC)	±1.902	0.694
3. 12.186+2.629(TDH)+0.528(VDH)+0.805(CH)	±1.910	0.674
Left side		
1. 13.196+1.768(UEB)+0.602(LEB)+1.278(TDH)+0.208(VDH)	±2.556	0.575
2. 14.058+3.022(UEB)+1.100(LEB)+0.574(USC)	±2.444	0.580
3. 14.870+1.752(TDH)+0.872(VDH)+0.404(CH)	±2.512	0.540

DISCUSSION:

Krogman and Iscan (1986) commented that the broken bone fragments recovered from crime scene should be measured and subjected to estimation of respective bone length and subsequently stature can be estimated from that reconstructed bone length by employing statural formulae for the concerned bone.

There were only few studies available on this aspect where in Muller (1935), Steele and Mc Kern (1969), Steele (1970), Mysorekar et al. (1980, 1982), Rao et al. (1989a, b), Shroff and Fakhruddin (1986) and Gupta and Nath (1998a,b,1997a) used linear segment lengths for estimation of bone length. Chandra and Nath (1984, 1985) used a single transverse measurement to estimate bone length, while certain studies Badkur and Nath (1989, 1990a, b) Nath and Badkur (1990, 1995) and Nath et al. (1995) used multiple dimensions of long bones i.e. linear, transverse, sagittal and circumferential to reconstruct either bone length or stature from fragmentary dimensions of long bones. Datta and Nath (2001, 2002) formulate linear regression equations for estimation of humeral length. Wright and Vásquez (2003) derived the equations by regressing bone segment length on bone length of Femur, humerus, tibia, and fibula. Chibba and Bidmos (2007) and Bidmos (2008, 2009) derived equations for estimation of stature. Somesh et.al (2011) formulates simple linear regressions to correlate five different segments with the total length of humerus. Chandran and Kumar (2012) formulate regression equations for reconstruction of femur length from its fragments in South Indian males and Mohanty, Sahu, and Das, (2012) formulate regressions for estimation of humeral length from its fragmentary portions.

The approach followed in the present study is different from the initial studies of Muller (1935) and Steele and Mc Kern (1969) for the purpose of reconstructing humeral length as both these studies incorporated only linear bone segments for this purpose. Considering the linear regression equations the best estimate of humeral length are obtained using TDH, UEB, and CH for both sides (table-2). The degree of accuracy in estimated humeral length is enhanced through multilinear regression equations (table-3).

CONCLUSION:

Different linear and multilinear regression equations formulated and presented in this study enable us to reconstruct humeral length in all those instances where skeletal remains of humerus are identified from the recovered skeletal material. It is essential for an expert to first identify the side of the recovered material before entering the measured dimensions of the segments in respective linear and multilinear regression formulae available for both the sides to reconstruct bone length.

REFERENCES:

Badkur P 1985. Estimation of bone length and stature from measurements of human long bones of Madhya Pradesh, India. Ph.D. Thesis, University of Delhi.

Badkur P and Nath S 1989. Estimation of bone length and stature using fragmentary measures of Humerus bone. *Ind. J. For. Sci*. 3: 23-25.

Badkur P. and Nath S 1990a. Use of regression analysis in reconstruction of maximum bone length and living stature from fragmentary measures of Ulna. *For. Sci. International*. 45: 15-26

Badkur P and Nath S 1990b. Fragmentary bone measures and regression analysis in prediction of bone length of radius. *J. Ind. Acad. For. Med.*12: 45-50.

Bass WM 1971.Human Osteology: A laboratory and field manual of the human skeleton, Archeological Society, Columbia, Missouri.123-137.

Bidmos M and Asala S 2005. Calcaneal measurement in estimation of stature of South African blacks. *Am J Phys Anthropol*. 126(3): 335-42

Bidmos MA 2008. Estimation of stature using fragmentary femora in indigenous South Africans. *Int J Legal Med*. 122(4): 293-9.

Bidmos MA 2009. Fragmentary femora: evaluation of the accuracy of the direct and indirect methods in stature reconstruction. *Forensic Sci Int.* 192(3): 131-5.

Chandra A, Dass, Ramji, and Khanna, JK 1966. Reconstruction of the total length of femur from its fragments. A preliminary report. *J. Anat. Soc. India*. 15: 92-95

Chandra NS and Nath S 1984. Estimation of Humeral length from a single fragmentary bone measure. *J. Ind. Acad. For. Sci*. 23: 11-14

Chandra NS and Nath S 1985. Reconstruction of Femoral and Humeral bone lengths using a fragmentary bone measure. *Ind. J. Phys. Anthrop*. Hum. Genet. 11: 123-128.

Chandran M and Kumar V 2012. Reconstruction of femur length from its fragments in South Indian males. *Journal of Forensic and Legal Medicine.* 19: 132-136.

Chibba K Bidmos MA 2007. Using tibia fragments from South Africans of European descent to estimate maximum tibia length and stature. *Forensic Sci Int*. 169(2-3): 145-51.

Datta S and Nath S 2001. Reconstruction of Humeral length from its fragments. In advances in Forensic Science. Bhasin MK and Nath S, editors. Department of Anthropology. University of Delhi.

Datta S and Nath S 2002. Use of transverse and circumferential dimensions in prediction of Fibular length. In: Guru AK and Shrivastava P, editors. In recent advances in Forensic Biology. New Delhi, Anmol Publications Pvt. Ltd. p. 25-34.

Gupta GD and Nath S 1996. Estimation of Femoral and Tibial lengths from fragmentary dimensions. *Police Research and Development.* Qr. I: 41-45.

Gupta GD and Nath S 1997a. Formulation of regression formulae for estimation of Humeral and Radial lengths from fragmentary dimensions. *Police Research and Development.* Qr. II: 28-33.

Gupta GD and Nath S 1997b. Reconstruction of Fibular length from fragmentary dimensions of Fibula. *Procs. X All India Forensic Science Conference, Bhubaneswar (11-13 Nov).* 3-5.

Gupta GD and Nath S 2000. Reconstruction of Fibular length from its transverse dimensions. *C.B.I. Bulletin*. VIII (8): 37-39.

Martin R and Saller K 1959. Lehrbuch der Anthropologie in Systematischer. Fischer Darstellung, Stuttgart.

Mohanty S, Sahu G and Das S 2012. Estimation of length of humerus from its fragmentary portions. *Journal of Forensic and Legal Medicine*. 19: 316-20.

Muller G 1935. Zur bestimmung der lange beschdigter extremitatenknochen. *Anthrop. Anz*. 12: 70-72.

Mysorekar VR, Verma PK, Nandedkar AN and Sharma TCSR. 1980. Estimation of stature from parts of bones-lower end of femur and upper end of radius. *Med. Sci. Law*. 20: 283-286.

Mysorekar VR, Nandedkar AN and Sharma TCSR 1982. Estimation of stature from parts of Humerus and Radius. *Med. Sci. Law*. 22: 178-180.

Nath S and Badkur P 1990. Reconstruction of stature through fragmentary measures of Radius bone. *Ind. J. For. Sci*. 4: 79-88.

Nath S and Badkur P 1993. Reconstruction of stature through fragmentary measures of Femur. *South Asian Anthropologist.* 14: 55-60

Nath S and Badkur P 1995. Stature estimation from fragmentary dimensions of Femur. *Ind. J. Criminol. and Criminalistics.* 26: 51-55.

Nath S and Gupta GD 2001. Prediction of bone length and stature from circumferential dimensions of Tibia. In: Basin MK and Nath S, editors. In advances in Forensic Science, Department of Anthropology, University of Delhi. p. 110-115.

Patel MP, Joshi NB and Dongre AV 1964. Regression equation of height on Tibial Length. *Ind. J. Med. Res.* 52: 531-534.

Rother P, Jahn W, Hunger H, and Kurp K1980. Determination of body height from fragments of the femur. *Gegenbaurs Morphol Jahrb*. 126(6): 873-83.

Shroff AG and Fakhruddin F 1986. Relationship between the length of Humerus and its fragments. *J. Anat. Soc. India*. 35: 109-114.

Simmons T, Jantz RL and Bass WM 1990. Stature estimation from fragmentary femora: a revision of the Steele method. *Forensic Sci.* 35(3): 628-36.

Somesh MS, Latha VP, Shilpa K, Mangala MP, Krishnamurthy A and Murlimanju BV 2011. Morphometric study of the humerus segments in Indian population. *Int. J. Morphol*. 29(4): 1174-80.

Steele DG and McKern TM 1969. A method for assessment of maximum long bone length and living stature from fragmentary long bones. *Am. J. Phys. Antropol.* 31: 215-227.

Steele DG and Stewart TD 1970. Estimation of stature from fragments of long limb bones. In Personal Identification in Mass Disaster, National Museum of Natural History, Washington.

Stewart TD 1979. Essentials of forensic anthropology, Springfield Illinios, Thomas.

Wright LE and Vásquez MA 2003. Estimating the length of incomplete long bones: forensic standards from Guatemala. *Am J Phys Anthropol.* 120(3): 233-51.