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Original Article

Anatomy Section

Prediction of Total Length of Humerus from its Fragments in West Bengal Population

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ABSTRACT

Introduction: Reconstruction of stature from human skeletal remains has long been considered as an important medico legal challenge. In absence of other bones like cranium or pelvis, anatomical knowledge of long bone even when only a fragment of it becomes available may help to meet that challenge through a series of estimation of length of long bone first and then reconstruction of stature of the unidentified individual.

Aim: To determine length of different segments of humerus and then reconstruction of total length of humerus, in West Bengal population using standard regression formula.

Materials and Methods: A total of 60 adult dry humerii, 30 belonging to right and 30 of left side of unknown age and sex were taken. Each bone was divided into five segments (H1, H2, H3, H4 and H5) by taking predetermined points on it. Such five parameters along with total length of humerus were measured to the nearest millimetre. The values were presented as mean±SD in mm separately for each side. The proportion of each segment to the total length was also calculated. Simple linear regression ($p < 0.01$) was used to correlate the length of each segment with total length. Later on, when multiple regressions were used to estimate total length, incorporation of variables was made through stepwise regression.

Results: The average total length of humerus on right side was 307.13±17.99 and on left side 297.77±19.78. The mean lengths of five segments, namely H1, H2, H3, H4 and H5 were 6.11±0.80, 34.07±1.44, 18.76±2.00, 16.22±2.13 and 32.51±2.70 mm on right and 6.03±0.73, 33.10±1.95, 18.12±1.68, 15.99±1.82 and 31.96±1.32 mm on left humerii respectively. When multiple linear regression was used, H2 alone contributing 65% and 76% showed significant changes in estimating total length of humerus in case of right and left sides respectively.

Conclusion: The present study revealed prediction of total length of humerus from detailed estimation of different segments of humerus among West Bengal population which may be treated in future as an useful reference not only for anatomists, forensic experts and archaeologists but also for orthopaedic surgeons undertaking reconstructive surgery for proximal and distal humeral fractures.

Keywords: Human skeleton, Long bones, Reconstruction, Segments

INTRODUCTION

Availability of plenty of human skeleton from excavation dates back to prehistoric age in most of the countries. Estimation of stature from such human skeletal remains has long been considered as an important medico legal challenge in the court of law [1,2]. In absence of pelvis or cranium, morphometric analysis of remains of long bones is used to indicate stature. Intact long bones of either upper or lower extremities have long been used in derivation of regression equations for stature estimation in different population groups [3,4]. The length of long bone was used to estimate stature by using Pearson's derivation of regression formulae [2]. In this aspect, length of long bones help the investigator to know the stature of the individual and use of more than one long bone can give more accurate result. Regression formulae have been accepted worldwide for determination of stature from various anthropometric dimensions. Thus, femur and tibia collectively remain as best for such assessment [5,6], but when these bones become unavailable, estimation of stature can be done through morphometric analysis of humerus [7].

Sometimes, long bones are presented in different fragmented states before forensic experts; which necessitated development of another method for assessment of maximal long bone length and living stature from fragmentary long bones. Estimation of total bone length from its fragments was first described by "Muller" in order to overcome the difficulty in availability of complete bone due to damage occurred by different types of accidents making them fractured [8].

Accordingly, five humeral segments were defined by using the margins of articular surface and key points of muscle attachments. Therefore, determination of total length of humerus has become possible by knowing measurements of its different segments. This is essential to assess sexual dimorphism also [8]. Racial difference has also been documented during exploration of relation between stature and length of long bones [5,6,9,10]. It is also believed that such morphometric knowledge of humeral segments is important for clinicians in the treatment of proximal and distal fragment fracture of humerus [11,12].

Taking into consideration of increased interest in recent past, studies on this topic on Indian population are meager especially in West Bengal. Therefore, the present study was attempted to estimate lengths of different segments of humerus and then reconstruct total length in West Bengal population using standard regression formulae.

MATERIALS AND METHODS

This was an observational study carried out in the Department of Anatomy, at Calcutta National Medical College, Kolkata, India, for the period of approximately one year from August 2015 to July 2016, on 60 unpaired dry adult humerii (right-30 and left-30) of unknown age and sex collected from different Medical Colleges of West Bengal. The bones which were normal with no appearance of damage or any pathological changes were selected.

The total length of humerus was measured first by using ruler as vertical distance from uppermost part of head of humerus to the ground where lower surface of trochlea was in contact. Then, each bone was divided into five segments as follows [13]:

i. H1 – Distance between most proximal point of humeral head and greater tuberosity.

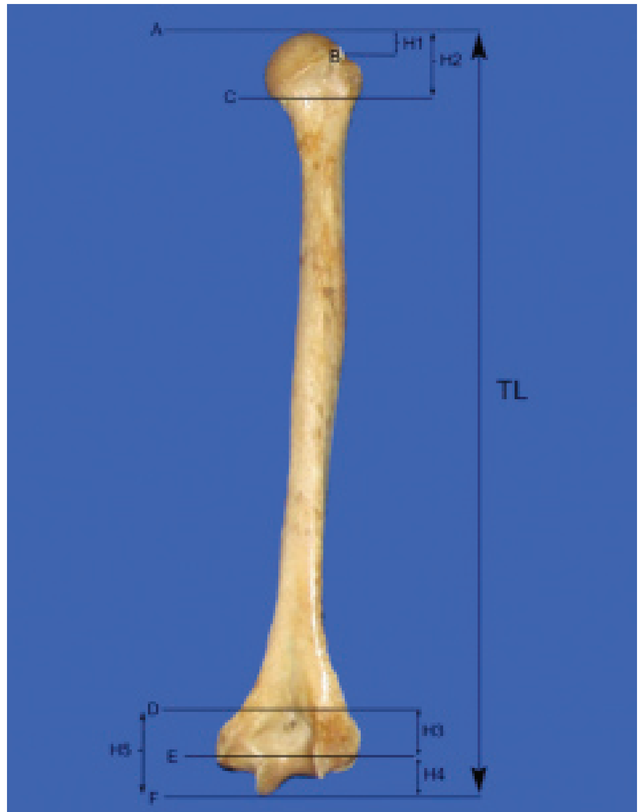
ii. H2 – Distance between most proximal point of humeral head and lower margin of anatomical neck.

iii. H3 – Distance between proximal and distal point of olecranon fossa.

iv. H4 – Distance between distal point of olecranon fossa and distal point of trochlea.

v. H5 – Distance between proximal point of olecranon fossa and distal point of trochlea.

In this way, lengths of various segments were measured by vernier caliper to the nearest millimetre [Table/Fig-1].



[Table/Fig-1]: Showing method of measurements of different segments of humerus.
TL: Total length (AF); H1: distance between most proximal point of humeral head and greater tuberosity (AB); H2: distance between most proximal point of humeral head and lower margin of anatomical neck (AC); H3: distance between proximal and distal point of olecranon fossa (DE); H4: distance between distal point of olecranon fossa and distal point of trochlea (EF); H5: distance between proximal point of olecranon fossa and distal point of trochlea (DF).

RESULTS

Statistical Analysis

Descriptive statistics, linear regression and regression equations were derived from statistical analysis using SPSS-version 16.00 software. Data were presented as Mean±SD and p-value of less than 0.05 was accepted as indicative of statistical significance. Independent 't'-test was employed to compare the linear measurements of H1, H2, H3, H4 and H5 segments between right and left sides of humerii. Initially, a simple linear regression was applied considering right and left side separately for each segment. Multiple regressions were used then to estimate the total length using measurement of segment of bone by incorporation of variables through stepwise regression.

Accordingly, following results were obtained:

a) Descriptive statistics: The mean length of humerus on right side was 307.13±17.99 mm., while on left side was 297.77±19.78, p = 0.06 [Table/Fig-2].

The mean lengths of different segments on right side were H1 = 6.11±0.80 mm, H2 = 34.07±1.44 mm, H3 = 18.76±2.00 mm, H4 = 16.22±2.13 mm and 32.51±2.70 mm and on left side, H1 = 6.03±0.73 mm, H2 = 33.10±1.95 mm, H3 = 18.12±1.68 mm, H4 = 15.99±1.82 mm and H5 = 31.96±1.32 mm respectively. Statistical significant difference was observed between right and left humerii only in case of measurement of

Parameters (mm.)	Right Humerus (n =30)	Left Humerus (n =30)	p-value
Total length	307.13±17.99	297.77±19.78	0.06
H1	6.11±0.80	6.03±0.73	0.70
H2	34.07±1.44	33.10±1.95	0.03
H3	18.76±2.00	18.12±1.68	0.18
H4	16.22±2.13	15.99±1.82	0.65
H5	32.51±2.70	31.96±1.32	0.33

[Table/Fig-2]: Showing morphometric measurements of different segments and total humeral length of both sides.

Right Humerus	H1	H2	H3	H4	H5
COE	0.086	0.806	0.525	0.448	0.539
p-value	0.651	<0.001**	0.003**	0.013*	0.002**
Left Humerus					
COE	0.281	0.871	0.652	0.622	0.572
p-value	0.133	<0.001**	<0.001**	<0.001**	<0.001**

[Table/Fig-3]: Showing simple linear regression co-efficients (COE) in the correlation between humeral length and different segments of both sides.

H2 [Table/Fig-2].

b) Simple linear regression: [Table/Fig-3] shows simple linear regression co-efficients (COE) and significance (p-value) in the correlation between humeral length and segments of humerii of both sides separately. On analysis, *correlation is considered as significant at 0.05 level (2-tailed) and ** correlation as significant at 0.01 level (2-tailed).

[Table/Fig-4a-e & 5a-e] Scatter diagram showing linear regression of right and left humerus with different humeral segments (H1, H2, H3, H4, H5).

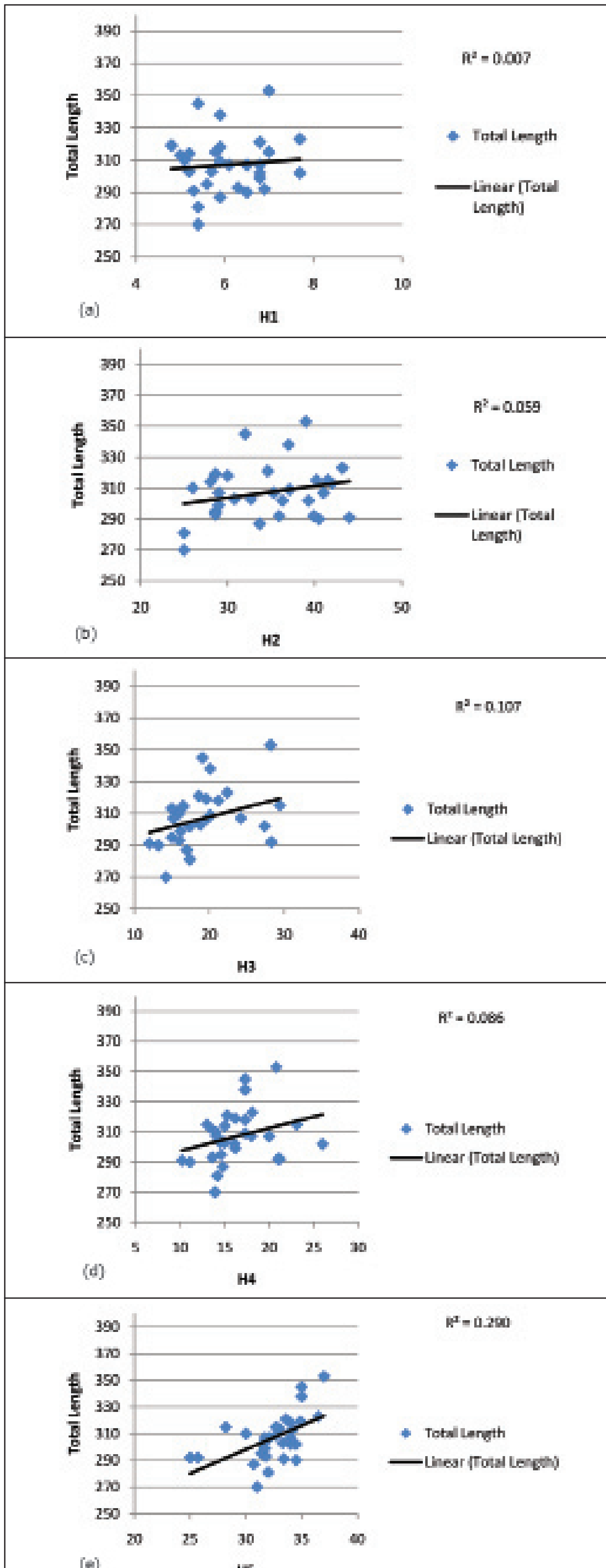
c) Simple linear regression equation: Following linear regression formula was used for estimation of total humeral length relative to different humeral segments (H1, H2, H3, H4, H5): y = a + b1H1 + b2H2 + b3H3 + b4H4 + b5H5

(y = total humeral length; a = constant; b1, b2, b3, b4 and b5 = regression-coefficients)

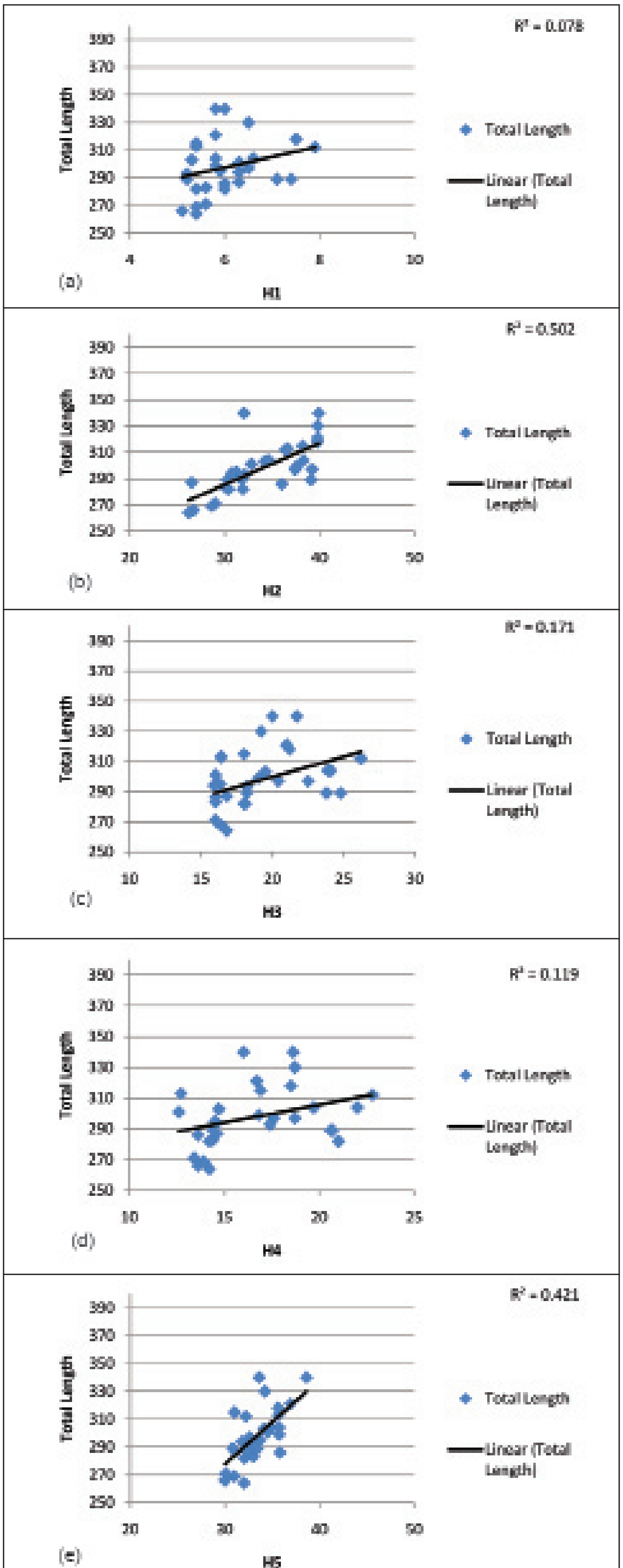
Accordingly, total length of humerus was derived as under: [Table/Fig-6]

d) Stepwise multiple regressions: In this method, when multiple regressions were used to estimate total length, incorporation of variables was made through stepwise regression in models as predictors and following results were obtained:

In right humerus: H2 (model 1) could only explain 65% (r2 = 0.65), H2 and H3 (model 2) as 72% (r2 = 0.72) and H2, H3 & H1 (model 3) as 76% (r2 = 0.76) statistical significant contribution for explanation or variation of total humeral length. So, best model is model 2.



[Table/Fig-4a-e]: Scatter diagram showing linear regression of right humerus with different humeral segments (H1, H2, H3, H4, H5).



[Table/Fig-5a-e]: Scatter diagram showing linear regression of left humerus with different humeral segments (H1, H2, H3, H4, H5).

In left humerus: H2 (model 1) could explain 76% (r2 = 0.76) and H2 and H4 (model 2) as 81% (r2 = 0.81) statistical significant contribution for explanation or variation of total humeral length. So, on the left side also, best model is model 2.

Therefore, on analysing the results of both sides, H2 segment was found as most important predictor for explanation or variation of total humeral length.

Right Humerus (n = 30)	Left Humerus (n = 30)
THL = 295.31 + [1.94 (H1)]	THL = 251.57 + [7.66 (H1)]
THL = -35.59 + [10.06 (H2)]	THL = 5.69 + [8.82 (H2)]
THL = 218.53 + [4.72 (H3)]	THL = 159.02 + [7.66 (H3)]
THL = 245.90 + [3.77 (H4)]	THL = 189.77 + [6.75 (H4)]
THL = 190.50 + [3.59 (H5)]	THL = 22.64 + [8.61(H5)]

[Table/Fig-6]: Showing simple linear regression formula for estimation of total humeral length relative to different humeral segments.

DISCUSSION

Projection of stature from bones has long been assumed to play an important role in identification of missing person in forensic anthropology. Height of individual is an extremely variable parameter which is influenced by a variety of confounding factors like age, sex, ethnicity etc. Therefore, many studies have shown that stature can differ from one individual to another according to different populations. As such, Pan measured maximum length of different limb bones among 142 male and female East Indian Hindus [14]. Stevenson studied 48 Northern Chinese male skeletons in Mongoloid group to find out ratio between bone length and height of individual [10]. Stature can also be estimated from a combination of two or more leg bones as suggested by Dupertuis sand Hadden when studied among American whites and blacks [15].

Humerus being the longest and largest bone of upper limb, estimation of stature by applying the regression formula can also be done from humeral length in absence of other more appropriate long bones like femur or tibia. Accordingly, total length of humerus was derived from its fragments by applying regression formulae among different population [13,16-19].

Similarly, in the present study, we obtained mean total length of humerii and their fragments separately for right and left sides and were compared with results obtained from Turkish [20], Spanish [21] and other Indian studies [13,16-19, 22-24].

Mean values of total length was identified as 307.13±17.99 mm on right and 297.77±19.78 mm on left side which when compared with other studies some differences were found [13,16-19, 22-24]. The reason could be due to the height of the individuals in those geographical regions.

The mean distance between the head and proximal part of greater tuberosity (H1) in our study was 6.11±0.80 mm on right and 6.03±0.73 mm on left side which was similar to those of other studies [18-19, 22-24], but the values are slightly lower in study done by Premchand and Manjappa [13].

In the previous studies, H2 segment was estimated to have an idea about relative height of greater tuberosity to determine the amount of subacromial clearance while elevating the arms and also for the treatment of isolated greater tuberosity fracture [11]. Accordingly, measurement of H2 segment in the present study was 34.07±1.44 mm on right and 33.10±1.95 mm on left side. These values when compared with other previously done studies, some differences were found [13,16-19,22-24]. This could be due to the results of diverse factors in those geographical regions.

Such variety of distances involving proximal part of humerus are important in cases of proximal humeral fractures which may extend along the epiphyseal lines of the proximal humerus and its segments causing their displacements to various degrees as reported previously by Somesh et al., [18].

The distal part of humerus has an unique anatomy as it freely articulate with radius and ulna. Complex distal humeral fracture may lead to neurovascular damage. Fractures of olecranon are common, about 10% among various upper limb injuries especially as a result of forced hyperextension trauma to elbow joint [12]. In an archaeological study, it was observed that, the measurement of H3 was 20.3±1.3 and 20.2±1.9 mm respectively for male and female German population [25], while the same distance among Turkish population was found as 24.2±2.07 mm and 23.9±2.63 mm on right and left humerii respectively [20]. Studies on Indian population revealed such mean value as 20.14±3.43 mm & 19.06±2.92 mm [18], 1.88±0.18 cm & 1.95±0.2 cm [19], 18.26±1.59 mm & 17.62±1.67 mm [13], 16.2±0.31 mm & 15.9±0.35 mm [22], 38.3±1.9 mm & 39.7±2.5 mm [23], 27.4±2.4 mm & 27.5±2.6 mm [24] on right and left sides respectively as against 18.76±2.00 mm & 18.12±1.68 mm observed in our study.

In our study, measurement of H4 segment was 16.22±2.13mm on right & 15.99±1.82 mm on left sides, whereas in Turkish population, the same measurement was 2.0±0.22 cm & 1.97±0.25 cm [20] on right & left sides respectively and in a study from Guatemala with forensic Maya samples, this distance was 14.2±1.8 mm on right side for male [8]. Therefore, it was evident that there are differences in the values obtained as against previous studies done on Indian population [13,15-19,22-24].

Finally, when we measured H5 segment, it was found to be 32.51±2.70 mm and 31.96±1.32 mm on right & left sides respectively. Akman et al., [20] found the same distance as 4.06±0.33 cm & 3.97±0.34 cm on right and left sides respectively. The similar measurements among different Indian studies were found as 37.26±4.71 mm & 35.72±4.30 mm [18], 3.33±0.26 cm & 3.41±0.28 cm [19], 32.70±2.51 mm & 31.64±2.30 mm [13], 31.7±0.32 mm & 31.8±0.28 mm [22], 34.5±3.6 mm [24] on right and left sides respectively.

In the present study, some differences were found in the mean values of different humeral segments when compared with other studies [13,15-19, 22-24]. This could be due to the results of diverse factors such as age, sex, race, environmental factors and genetic factors which affect anatomical reference points which are taken as criteria in the measurements of humerii.

Many studies have incorporated regression analysis as appropriate method to define relationship between length of long bone and its fragments [16-18]. Therefore, knowledge of length of individual segments taken in the present study have enough scope to derive regression equation to find out the length of humerus precisely which will help in calculating stature of the individual with reasonable accuracy among population of West Bengal. Accordingly, simple linear regression formula was used for estimation of total humeral length relative to different humeral segments (H1, H2, H3, H4, H5) for both sides separately. Later on, when multiple regressions were used to estimate total length, incorporation of variables was made through stepwise regression in models as predictors, H2 segment was found as most important predictor for explanation or variation of total humeral length on both sides.

Since the present study was done on populations of West Bengal, which have not yet reported, previously done study by using standard regression formula that can be applied to derive stature of the individual with reasonable accuracy [14].

LIMITATIONS

The humerii used for the present study were of unknown age and sex. Also, in this study, there was no information regarding the height, nutritional status etc., of individuals whose bones were used. Therefore, it was not possible to correlate measurements of segments of humerus with height of the individual person. Thus, a more detailed analysis could have been done if these data were available.

CONCLUSION

The results of our study may help forensic, anthropometric and archaeological investigators regarding identification of the skeletal remains of unknown bodies by using regression equations and also help orthopaedic surgeons to place various implants for the treatment of fractures involving humerus. Further, studies need to be designed in this perspective in order to get more accurate estimates among population of

West Bengal considering age and sex.

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REFERENCES

[1] Beddoe J. On the stature of the older races of England as estimated from the long bones. *J Anthropol Inst*. 1888;17:202-07.
[2] Pearson K. Mathematical contribution to the theory of evaluation. On the reconstruction of the stature of prehistoric races. *Philos Trans R Soc Lond*. 1899;192:169-244.
[3] Nath S & Badkur P. Reconstruction of stature from long bone lengths. *Int J Osteoarchaeol.* 2002;1:109-14.
[4] Petersen HC. On the accuracy of estimating living stature from skeletal length in the grave and by linear regression. *Int J Osteoarchaeol*. 2005;15:106-14.
[5] De Mendonça MC. Estimation of height from the length of long bones in a Portuguese adult population. *Am J Phys Anthropol*. 2000;112(1):39-48.
[6] Radoinova D, Tenekedjiev K & Yordanov Y. Stature estimation from long bone lengths in Bulgarians. *Homo*. 2002;52(3):221-32.
[7] Kate BR and Majumdar RD. Stature estimation from femur and humerus by regression and autometry. *Acta Anat*. 1976; 94:311- 20.
[8] Wright LE, Vásquez MA. Estimating the length of incomplete long bones: Forensic standards from Guatemala. *Am J Phys Anthropol*. 2003;120(3):233-51.
[9] Trotter M, Gleser GC. Estimation of stature from long bones of American whites and Negros. *Am J Phys Anthropol.* 1952;10:463–514.
[10] Stevenson PH. On racial differences in stature long regression formulae, with special reference to stature reconstruction formulae for Chinese. *Biom*. 1929;21(1-4):303–33.
[11] Green A & Izzi J Jr. Isolated fractures of the greater tuberosity of the proximal humerus. *J Shoulder Elbow Surg*. 2003;12(6):641-49.
[12] Jupiter JB & Mehne DK. Fracture of distal humerus. *Orthopedics* 1992;15(7):825-33.
[13] Premchand SA, Manjappa T. Reconstruction of humeral length from measurements of its segments in South Indian population. *International Journal of Scientific Research*. 2014;3(8):1956-59.
[14] Pan N. Length of long bones and their proportion to body height in Hindus. *J Anat*. 1924; 58:374-78.
[15] Dupertuis CW, Hadden Jr JA. On the reconstruction of stature from long bones. *Am J Phys Anthropol*. 1951; 9(1):15–54.
[16] Salles AD, Carvalho CRE, Silva DM, Sautana LA. Reconstruction of the humeral length from the measurements of its proximal and distal segments. *Braz J Morphol*. 2009;26(2):55-61.
[17] 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(4): 783-86.
[18] Somesh MS, Prabhu LV, Shilpa K, Pai MM, Krishnamurthy A, Murlimanju B. Morphometric study of the humerus segments in Indian population. *International Journal of Morphology.* 2011;9(4):1174-80.
[19] Ashiyani ZA, Jadav HR. The Segmental Measurements of Humerus. *International Journal of Scientific Research* 2014; 3(10): 434-35.
[20] Akman SD, Karakas P & Bozkir MG. The morphometric measurements of humerus segments. *Turk J Med Sci.* 2006;36(2):81-85.
[21] Muñoz JI, Liñares-Iglesias M, Suárez-Peñaranda JM, Mayo M, Miguéns, X, et al. Stature estimation from radiographically determined long bone length in a Spanish population sample. *Forensic Sci Int*. 2001;46(2):363- 66.
[22] Kishve P, Joshi M. Morphometric study of humerus in Western region of India. *Indian J. Appl Res*. 2015;5(11):463-64.
[23] Desai SD & Shaikh HS. A morphometric study of humerus segments. *J Pharm Sci & Res*. 2012;4(10):1943-45.
[24] Rai R, Chawla M. Morphometry of adult humerus bone in Moradabad region. *Int J Bio & Adv Res*. 2014;5(3):163-65.
[25] Churchill SE & Smith FH. A modern human humerus from the early Aurignacian of Vogelherdh.le (Stetten, Germany). *Am J Phys Anthropol*. 2000;112(2):251-73.

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