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Assessment Of Humeral Length From Morphometric Measurement Of Its Segments

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KEYWORDS

Humerus; Osteometry; Forensic anthropology; Fragmented bones;Skeletal identification; Regression analysis.

Abstract:

Background: The humerus plays a significant role in forensic and anthropological investigations, particularly in estimating bone length through segmental measurements.As one of the strongest long bones, it often remains useful for identification even when fragmented.

Objective: To measure the morphometry of different segments of the humerus by using Hepburn's osteometric board, scales and digital vernier calipers.

Methods: In this study,80 dry humeri (37 left & 43 right) were examined. Maximum humeral length (MHL) and seven other segments were measured. The mean values of MHL and all individual segments were calculated, and the obtained data were used to derive regression equations.

Results: The mean MHL was 29.87 ± 1.78cm on the left side and 29.98 ± 1.59cm on the right side.A significant positive correlation was observed between MHL and segmental measurements H2, H3, H4, H6 and H7 ($p < 0.05$) on the left side, and H2, H3, H4, H7 ($p < 0.05$) onthe right side. Regression equations were derived to estimate maximum humeral length from segmental measurements on both sides.

Conclusion: The humerus is useful for forensic identification even when fragmented. Segmental correlations and regression equations allow reliable estimation of maximum humeral length, particularly in cases involving incomplete or commingled skeletal remains in medico-legal investigations

Introduction:

Humerus plays very important role in forensic and anthropological practice because of its importance to determine its length from the segmental measurement. By measuring different segments of the humerus, the total length of the humerus can be determined. The humerus articulates with the scapula proximally at the glenohumeral joint so it participates in the movements of the shoulder. Also, the humerus articulates with the radius and ulna distally at elbow joint. Many believe that the humerus is one of the strongest long bones in the skeleton and, even when fragmented, it can still be used in skeletal autopsies [8]. Fragmented bones, often with damaged or missing ends, are commonly encountered in forensic investigations. In both archeological and forensic contexts, pieces of long bones- resulting from trauma, mutilation, destruction and post-mortem gnawing by wild animals- may sometimes represent the only evidence for establishing identity [29]. Estimating stature from bone fragments becomes particularly challenging when only partial remains are available, such as after mass disasters or blast-related injuries. In many cases, these fragmented bones are often overlooked by forensic anthropologists because they are assumed to provide little or no useful information.A possible solution to this issue was proposed as early as 1935 by Muller, who provided scientific basis for the estimation of length of bone through the fragments [17]. Some studies also suggested that there is great variation in different measurements of humerus among different races e.g. Spanish, Asian, Portuguese and Bulgarian populations.Morphometric measurements of humeral length can be used by forensic anthropologists, forensic experts and forensic scientists for determination of human stature from skeletonized dead bodies remains or human skeleton remains.Human population differ in their physical characteristics, and these variations are reflected in their skeletal structures. As a result, bones exhibit measurable differences among populations. The average measurements of segments of long bones, particularly the humerus, can therefore assist investigators in establishing the identity of skeletal remains [4]. In forensic anthropology, estimating an individual's stature using measurements from segments of long bones is considered an important technique. Steele and McKern developed a method based on the proportional relationship between distances measured at specific fixed points on bones and their total length [7]. Estimation of humeral length is also important in medicolegal investigations. Morphometric data of humeral segments are valuable for clinicians, particularly in the management and treatment of fractures involving the proximal and distal ends of the humerus [18]. Conventional osteometric techniques have long been used to estimate the total length of the humerus from its fragmented remains.A fall on an outstretched hand is a common cause of fractures of the distal end of humerus. Fractures involving the distal portion of the humerus often present significant reconstructive challenges and may lead to various complications. Consequently, these injuries require special attention from orthopaedic surgeons [22]. Morphometric analysis of the distal end of the humerus is important because olecranon fractures account for approximately 10% of all upper extremity injuries [20]. Several methods are available for estimating an individual's stature from skeletal remains. Among these, regression analysis is considered one of the most reliable techniques. It is particularly useful for establishing the relationship between the length of long bones and the living stature of an individual, as well as for determining the relationship between measurements of bone fragments and the total length of the bone [21]. The present study will determine regression equations for calculating maximum humeral length from the measurement of its segments, which may be useful for estimation of stature in skeletal autopsies, and archeological studies. It will also help orthopedic surgeons in reconstruction of the fragments.

Material and Method:

The present study was conducted on 80 dry humeri (37 left and 43 right) collected from the skeletal collections of the Department of Anatomy at National Institute of Medical Sciences and Research, Jaipur, Rajasthan, after obtaining the necessary permission from the Ethics committee of National Institute of Medical Sciences and Research, Jaipur, Rajasthan.

The maximum humeral length was determined using Hepburn's osteometric board. The lengths of various segments of humerus weremeasured using transparent scales and digital vernier calipers.

A total of eight measurements were taken along the longitudinal axis of the humerus as shown in figure 1, are as follows:

MHL (A-F) - Maximum Humeral Length i.e., the distance between the most proximal point on the humeral head and the most distal point on the trochlea of humerus.

H1 (A-B) - The distance between the most proximal point on the humeral head and the most proximal point on the greater tuberosity.

H2 (B-C) - The distance between the most proximal point on the greater tuberosity and lower margin of the anatomical neck of humerus.

H3 (A-C) - The distance between themost proximal point on the humeral head and lower margin of the anatomical neck of humerus.

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H4 (C-D) - The distance between the lower margin of the anatomical neck of the humerus and the most proximal point on the edge of olecranon fossa.

H5 (D-E) - The distance between the most proximal point and the most distal point on the edge of olecranon fossa.

H6 (E-F) - The distance between the most distal point on the edge of olecranon fossa and the most distal point on the trochlea of humerus.

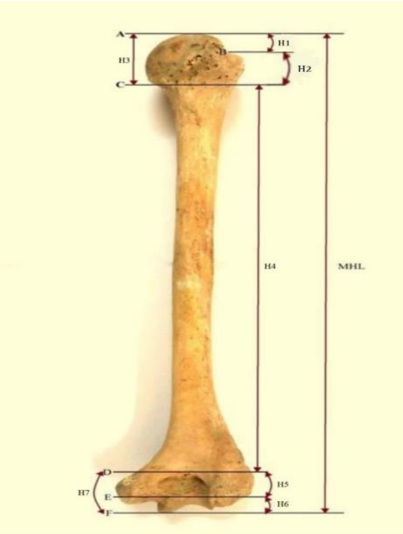

Figure 1:Measurements taken along the longitudinal axis of humerus

Observation and Result:

H7 (D-F) - The distance between the most proximal point on the edge of olecranon fossa and the most distal point on the trochlea of humerus.

After obtaining all the measurements, the mean value of each segment was calculated. The mean values thus obtained were subjected to statistical analysis to derive regression equations.

The descriptive statistics of maximum humeral length and various segmental measurements of the humerus for the left and right sides are presented in Table 1 and Table 2, respectively.

In the left humerus, the maximum humeral length ranged from 25.5 cm to 34.5 cm, with a mean value of 29.87 ± 1.78 cm. Among the different segments measured, H4 demonstrated the highest mean value (228.3 ± 15.7 mm), whereas H1 showed the lowest mean value (4.29 ± 1.55 mm).

In the right humerus, the maximum humeral length ranges from 26.6 cm to 33.8 cm, with a mean value of 29.98 ± 1.59 cm. Similar to the left side, H4 exhibited the highest mean value (229.7 ± 13.5 mm), while H1 recorded he lowest mean value (4.57 ± 1.42 mm).

Variables(Left Side)	**Minimum**	**Maximum**	**Median (IQR)**	**Mean ± SD**
MHL (cm)	25.5	34.5	29.8 (28.9-31.1)	29.87 ± 1.78
H1 (mm)	1.65	8.85	4.21 (3.12-5.43)	4.29 ± 1.55
H2 (mm)	19.26	35.34	28.36 (26.32-30.73)	28.71 ± 3.49
H3 (mm)	27.49	38.69	33.48 (31.11-36.16)	33.52 ± 3.16
H4 (mm)	192	273	227 (220-238)	228.3 ± 15.7
H5 (mm)	14.16	22.79	17.95 (16.67-19.59)	18.2 ± 2.18
H6 (mm)	8.38	20.99	14.66 (12.76-15.49)	14.21 ± 2.66
H7 (mm)	26.17	38.37	32.62 (30.38-34.38)	32.34 ± 2.81

Table 1: Descriptive statistics of MHL and different segment of humerus of left side

Table 2: Descriptive statistics of MHL and different segment of humerus of right side

Variables (Right Side)	Minimum	Maximum	Median (IQR)	Mean ± SD
MHL (cm)	26.6	33.8	30 (28.75-31)	29.98 ± 1.59
H1 (mm)	1.6	8.92	4.56 (3.9-5.18)	4.57 ± 1.42
H2 (mm)	22.11	35.74	29.41 (26.99-31.21)	29.03 ± 3.08
H3 (mm)	28.36	39	33.72 (32.22-35.51)	33.71 ± 2.85
H4 (mm)	203	262	232 (220-238)	229.7 ± 13.5
H5 (mm)	13.59	21.62	17.35 (15.55-18.60)	17.28 ± 2.14
H6 (mm)	8.53	26.05	16.79 (14.41-18.81)	16.42 ± 3.87
H7 (mm)	26.82	39.2	33.7 (32.2-35.72)	33.62 ± 2.78

To determine the relationship between the maximum humeral length (MHL) and the different segmental measurements of the humerus, regression analysis was performed. The purpose of this analysis was to assess whether the lengths of individual humeral segments could be used to predict the maximum humeral length.

Table 3 and Table 4 presented the regression equations of Maximum humeral length (MHL) on different segments of humerus bone of left and right side, respectively.

Table 3: Regression equations of Maximum Humeral Length (MHL) on different segments of humerus bone of left side

Regression Equations	F-test	P - Value	Significance
MHL = 28.35 + 0.355 (H1)	3.733	0.06147	Not Significant
MHL = 24.52 + 0.186 (H2)	5.392	0.02618	Significant
MHL = 20.45 + 0.281 (H3)	11.64	0.00165	
MHL = 4.39 + 0.112 (H4)	1017	< 0.0001	
MHL = 25.32 + 0.25 (H5)	3.642	0.06458	Not Significant
MHL = 26.78 + 0.218 (H6)	4.14	0.04952	Significant
MHL = 23.06 + 0.211 (H7)	4.37	0.0439	

Table 4: Regression equations of Maximum Humeral Length (MHL) on different segments of humerus bone of right side

Regression Equations	F-test	P - Value	Significance
MHL = 29.45 + 0.117 (H1)	0.462	0.5007	Not Significant
MHL = 22.81 + 0.247 (H2)	12.25	0.00114	Significant
MHL = 19.28 + 0.318 (H3)	19.83	< 0.0001	

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MHL = 3.953 + 0.114 (H4)	528	< 0.0001	
MHL = 27.81 + 0.126 (H5)	1.224	0.27497	Not Significant
MHL = 28.526 + 0.089 (H6)	2.02	0.16282	
MHL = 21.784 + 0.244 (H7)	9.18	0.00422	Significant

Regression analysis revealed that the Maximum Humeral Length (MHL) can be significantly predicted using H2, H3, H4, H6, and H7 on the left side, and H2, H3, H4, and H7 on the right side ($p < 0.05$). Among all segmental measurements, H4 showed the highest predictive accuracy bilaterally, making it the most reliable parameter for estimating total humeral length in the present population. In contrast, H1 and H5 on both sides, as well as H6 on the right, did not show significant associations with MHL ($p > 0.05$), and therefore have limited predictive value.The regression equation derived from these measurements help in estimating the total humeral length from fragmentary bone segments, which may be particularly useful in forensic anthropology, osteology, and anthropometric studies.

Discussion:

The total length of humerus can be assessed by the morphometric measurement of its segments. In the present study, morphometric measurements of maximum length of humerus and its different segments (H1-H7) were analyzed to evaluate the correlation and regression relationships between them. In the present study, the maximum humeral length and different segmental measurements of the humerus were recorded for both left and right sides. Among the measured segments, H4 showed the highest mean value, while H1 represented the smallest segment on both sides. These findings are comparable with the observations reported in previous studies, where segmental measurements of long bones have been shown to correlate significantly with the total bone length.

In the present study, the mean values of MHL were found to be 29.87 ± 1.78 cm on the left side and 29.98 ± 1.59 cm on the right side. These findings are comparable to those reported by Jahan S et al.[12] and Desai S.D et al.[8], who reported mean MHL values of 29.02 ± 2.78 cm on the left side and 29.12 ± 2.87 cm on the right side, and 28.94 ± 2.18 cm on the left side and 29.23 ± 2.29 cm on the right side, respectively.

In our study, the mean values of H1 segment were found to be 4.29 ± 1.55 mm on the left side and 4.57 ± 1.42 mm on the right side. In the previous studies the mean values of H1 were higher when compared with our study. The values reported by Premchand SA et al.[22] were 5.12 ± 1.45 mm on the left side and 5.76 ± 1.43 mm on the right side, while the values reported by Somesh MS et al.[25] were 5.8 ± 1.5 mm on the left side and 5.9 ± 1.1 mm on the right side.

The mean values of segment H2 i.e. the distance from the most proximal point of the greater tubercle to the most distal point of anatomical neck, recorded in our study were 28.71 ± 3.49 mm on the left side and 29.03 ± 3.08 mm on the right side.

In the present study, the mean values of H3 were found to be 33.52 ± 3.16 mm on the left side and 33.71 ± 2.85 mm on the right side which are in slight correlation with the study conducted by Srimani P et al.[26], who reported mean H3 values of 33.10 ± 1.95 mm on the left side and a slightly higher value of 34.07 ± 1.44 mm on the right side.

In the present study, the mean values of H4 segment were found to be 228.3 ± 15.7 mm on the left side and 229.7 ± 13.5 mm on the right side. However, most of the reference studies have reported H4 measurements based on sex (male and female) rather than laterality. The values reported by Mohanty S et al.[17] were 213.25 ± 2.62 mm for the male and 199.83 ± 2.56 mm for the female and the values reported by Ali DM et al.[2] were 23.31 ± 0.72 cm for male and 21.98 ± 0.63 cm for female.

The mean values of segment H5 in the present study were found to be 18.2 ± 2.18 mm on the left side and 17.28 ± 2.14 mm on the right side. These values are in correlation with study conducted by Premchand SA et al.[22], who reported mean H5 values of 18.26 ± 1.59 mm on the left side and 17.62 ± 1.67 mm on the right side.

In our study, the mean values of H6 segment were recorded as 14.21 ± 2.66 mm on the left side and 16.42 ± 3.87 mm on the right side. Previous studies conducted by Srimani P et al.[26], Naqshi BFet al.[20], and Premchand SA et al. [22] reported mean values of 15.99 ± 1.82 mm (left) and 16.22 ± 2.13 mm (right); 1.43 ± 0.16 cm (left) and 1.41 ± 0.15 cm (right); and 14.44 ± 1.43 mm (left) and 14.02 ± 1.32 mm (right), respectively.

In the previous studies conducted by Premchand SAet al.[22] and Srimani P et al.[26], the mean values for H7 segment were 32.70 ± 2.51 mm on the left side and 31.64 ± 2.30 mm on the right side, and 31.96 ± 1.32 mm on the left side and 32.51 ± 2.70 mm on the right side, respectively, which are slightly different from the present values of 32.34 ± 2.81 mm on the left side and 33.62±2.78 mm on the right side.

Regression analysis demonstrated that H2, H3, H4, and H7 provided statistically significant equations for the estimation of MHL on both sides, while H6 showed significance only on the left side. Among these variables, H4 emerged as the most reliable predictor. This suggests that measurements related to the humeral shaft have greater predictive value than proximal or distal fragments alone.Similar conclusions have been drawn by Bhusaraddi PS et al. [5], Prashanth KU et al. [21], Nanayakkara D et al. [19], and Tetiker Het al. [28], who emphasized the usefulness of shaft segments in reconstructing humeral length. Population-specific regression equations have been recommended by several authors, including Ali DM et al. [2]and Vinaykumar K et al. [29], as regression models vary across ethnic and regional groups.

The variations observed between the present findings and previous studies highlight the importance of population-specific standards in osteometric analysis. Genetic background, nutritional status, and environmental factors may influence bone growth patterns, limiting the direct applicability of regression equations derived from other populations.

Conclusion:

The present study demonstrates that the humerus is a valuable long bone for forensic identification, even in fragmented state.

The significant correlations and regression equations derived from selected humeral segments enable reliable estimation of maximum humeral length, particularly in cases involving commingled, dismembered or incomplete skeletal remains such as those encountered in mass disasters, explosions, and medico-legal investigations.

Among the evaluated segments, the mid-shaft (H4) showed the highest predictive accuracy, making it the most dependable parameter for reconstructing humeral length from fragments.

The population-specific regression models generated in this study can therefore assist forensic experts in biological profile reconstruction when complete bones are unavailable.

Further studies incorporating larger sample sizes, known stature, and sex-specific analysis are recommended to enhance the applicability and precision of these findings in forensic practice.

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