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Somatometric Evaluation of Long Bones of the Upper Extremity: A Forensic Tool

Abstract

Somatometric techniques are important tools in forensic investigation as well as in studying biological variation. The present study investigated the long bones of the upper extremity to ascertain which one will be more appropriate to generate regression equations for prediction of BH. Four long bone lengths (HL UL, RL and CL) were evaluated subcutaneously. BH was taken using Anthropometer, while randomly HL, UL, RL and CL were measured on the right side of the body from a pull of 211 subjects using measuring tape.

The findings of the present study indicate that the correlation 'r' between BH and the right upper limb measurements were significant for HL, UL, RL, in the overall population; the highest correlation between the dependent variable BH and the independent variable (UL) in overall population was 0.82 (P< 0.0001). In the females the correlation was significant for HL UL, RL, and CL; the highest correlation was found in UL, r=0.71 (P< 0.0001) the least was indicated by CL, r =–0.25. In the males the study revealed positive significant correlation for HL UL, and RL, The highest correlation was seen in UL, r=0.71 (P< 0.0001) while the least was 0.26 (P=0.02) as seen in HL. This present study shows that the UL is a veritable dimension in the estimation of BH for the Igbos because the Pearson's correlation coefficient 'r' obtained was the heights amongst that obtained for the other segments HL, RL and CL. Also the coefficient of determinant 'R' for testing model adequacy was highest for UL which had a lower SEE.

Keywords: Upper limb; body height; Forensic anthropology; Igbos

Research Article

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Abbreviations: BH: Body Height; HL: Humeral Length; RL: Radial Length; UL: Ulna Length; CL: Clavicle Length; F: Female; M: male; R: Multiple Correlation Coefficient Value; R^2: Percentage Contribution by the Explanatory Variable to the Variation in the Dependent Variable (BH); R^2adjusted: Compares the Regression Models Containing Different Number of Explanatory Variables (Upper Limbs Segments i.e. HL, RL, UL, and CL); SEE: Standard Error of Estimate (Predicts the Deviation of Estimated BH from the Actual BH)

Introduction

Somatometric techniques are employed in the measurement of the living body and cadaver and help in studying biological variations in humans. Such techniques are useful in forensic/ anthropological investigations to estimate the chronological age and even stature of a given population or individual. The prediction of the dimension of one body segment from another or to relate the proportions of one body segment to another has also gained importance in various area of modern science. In growth and development, the relationships between body segments are used in the assessment of normal growth as well as in scientific syndromes [1-4].

The relationship between specific body dimensions is also important in the identification of criminals and victims. In conditions where the available evidences are skeletal remains [5-6], or complete body part/ fragmented parts, Anthropologists/ Forensic Scientist are continually putting forward means to evaluate and estimate sex, age, height and race, (the big four of Forensic Anthropology). In some places, there are times when complete body parts (either upper or lower extremities) are deposited along the road by unknown persons. Such deposited body parts are either carted away by animals or crushed into pieces by moving vehicles. A time, the culprits and the person whose body were mutilated were never identified.

This study tries to evaluate the length of the long bones of the right upper extremity, subcutaneously, in other to generate possible regression formula for BH estimation of the study population (Igbo). This is because the identification of a person is important in the living as well as in the dead. In the living it is required in civil matters and criminal issues. In the dead it is important for proper dead body disposal and in unknown bodies [7].

The Igbo are a group of distinguished people who live in the Southeastern Nigeria. They are one of the three major ethnic groups in Nigeria [8]. They are seen in villages, towns and cities scattered over the Eastern part of Nigeria, South of the River Benue and East of River Niger, which is in the rain forest belt of the country [9] and also in the diaspora [10]. Igbos occupies an area of about 15,800 square mile (about 41,000 square kilometers) which is located between Latitude 5º and 7º North, and between 6º and 8º East of the Greenwich Meridian. They are bounded to the East by the lands of the Ibibio and the Cross River, to the South by the Ijaw speaking people, to the West by the Edo ethnic group and to the North by the Igala and the Idoma speaking people [11-13].

Materials and Method

Participants were randomly selected from a pull of 211 persons [14] and attention was paid on the evaluation of the lengths of the long bones of the upper extremity after informed consents were given by the subjects.

Study location

This study was conducted in Imo State, Nigeria and it took eight (8) months to be completed.

Demographics

The following demographic information was collected: age, sex, and state of origin. This is very important in any Somatometric study because they help to establish variability within populations.

Exclusion criteria

Pregnant women and subjects with musculo-skeletal disorder affecting body height and upper limb were excluded from this study.

Inclusion criteria

Only participants from the Igbo states who were apparently healthy were included in the study.

Anthropometrics

Body height (BH): This was measured to the nearest 0.1cm using an Anthropometer with subjects standing without shoes with the heels held together, toes apart, and the head held in the Frankfort plane [15].

Humeral length (HL): This the distance immediately below the acromioclavicular joint where the head of humerus is felt, to inferior part of the capitulum where the radius articulates with the humerus when the arm is abducted.

Ulna length (UL): The subject's elbow was flexed to 90º with the fingers extended in the direction of the long axis of the forearm, and the distance between the most proximal point of the olecranon and the tip of the styloid process of the ulna was measured [16].

Radial length (RL): The distance measured in cm where the head of the radius articulate with the humerus (elbow joint) to the radial styloid process palpated in the anatomical snuff box.

Clavicular length (CL): The acromial end is palpated 2-3cm medial to the lateral border of the acromion, when the arm is alternately flexed and extended, then the length in cm is measured from the sternal end to the acromioclavicular joint.

The long bones of the upper extremity were accessed subcutaneously [17] and measurement were taken using tape placed at the landmarks described above.

Stastical Analysis

The data analysis was carried out using statistical package for social sciences (SPSS 17.0 software). In summarizing the data, the Minimum, Maximum, Mean and Standard deviations were estimated and presented. A comparison of difference of variable in females and males was also carried out. To test the relationship between BH and dimensions of long bones of the upper extremity, Pearson correlation was performed. The prediction function was derived through linear regression for each of the measurement with BH for the overall population, males and females separately. Finally the predicted/estimated values of BH were compared with that of observed/actual value.

Results

The general Somatometric characteristics of the study population are shown in Table 1. The descriptive statistics for both the females and males samples is shown in Table 2. We can see the standard deviation, the mean, and the maximum and minimum values of the Somatometric variables. All the Somatometric dimensions measured directly showed statistically significant differences between females and males, $p<0.0001$ with females having a lower mean value than males (Table 3).

The correlation coefficient between BH and the right upper extremities dimensions (RL, UL, HL and LC) in the study population was found to be statistically significant and positive, indicating a strong relationship between BH and right upper extremity dimensions, but there was no significant correlation between BH and CL. The highest positive correlation was observed in UL, r= 0.822 while the least was observe in HL r=0.393 (Table 4). For the females, the least significant correlation was observed in the CL, r =-0.245 while the highest value was obtained in UL r=0.713. In the male population, significant and positive correlation was recorded between BH and right upper extremity segments. The least significant correlation was observed in HL, r = 0.257 while the highest was observed in UL, r= 0.713 (Table 4).

The Constant, Regression coefficient and Variation explained (R^2) derived for each of the right upper extremity measurements with BH are shown in Table 5 for the overall population and Table 6 for females and males. The values indicate that the constant for the HL was higher than that for RL, and UL, the regression coefficients were highly significant indicating that they are contributing for the prediction of BH. The variation explained (R^2x100) showed that it ranges from 15.4% to 67.6 % in the overall population. The best prediction power is observed in UL in the study population. For the females the variation explained ranged from 5.9% to 50.9%, with the UL having the best predict power while the least goes for the CL. In the males, the variation explained ranged from 6.6% to 50.9%, with the UL having the highest prediction power while the HL contributed the least to the variation explained.

The Regression coefficient for the CL was not significant in the overall population as well as in the males but was significant in the females. This means that the CL did not contribute to the variation explained in the overall population and males but contributed to that of the females, i.e. R^2 X 100 equals 6%. Tables 7 and 8 represent the values for R^2, Adjusted R^2, and SEE of the

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right upper extremities variables in the overall population, females and males respectively. The best simple linear regression model was developed using UL and this has the highest values for the coefficient of determination R^2 as 0.676, $R^2_{Adjusted}$ as 0.672 and multiple correlation coefficient R as 0.822 in the overall population.

In the females, the best simple linear regression model was developed using UL and this has highest values for the coefficient of determination R^2 as 0.509, R^2Adjusted as 0.499 and multiple correlation coefficient R as 0.713 with a 3.7993 SEE. In the males, the best simple linear regression model was developed using UL and this has highest values for the coefficient of determination R^2 as 0.509, $R^2_{Adjusted}$ as 0.492 and multiple correlation coefficient R as 0.713 with a 4.7782 SEE.

The best simple equation developed for the overall population, females and males respectively are: $BH_{overall\ population}$ = 61.105+3.604(UL), BH_{female} = 86.283+2.662(UL) and BH_{male} = 85.334 + 2.882(UL). BH could also be estimated using other dimension of the right upper extremity, the regression equations generated are also in Tables 8-10. The mean predicted value of BH through the regression function was similar to the mean observed value; however the minimum and maximum value indicated that there were differences in the predicted and observed value; the minimum predicted value overestimates the minimum observed value in the overall population, females and males while the maximum predicted value underestimates the maximum observed value in the overall population, females as well as in the males (Tables 11 &12).

Table 1: Descriptive Statistics of the Overall Population.

	N	Minimum	Maximum	Mean	Std. Deviation
AGE (years)	211	16.00	45.00	23.58	4.95
BH (cm)	211	149.00	190.00	167.55	9.10
RL	203	23.00	33.50	28.18	2.08
UL	84	25.00	34.00	29.06	1.87
HL	202	21.00	39.00	29.96	3.35
CL	186	8.60	22.00	14.62	3.09

Table 2: Descriptive Statistics of the Females and Females.

Variables	Females					Males				
	N	Minimum	Maximum	Mean	Std. Deviation	N	Minimum	Maximum	Mean	Std. Deviation
AGE (years)	123	16.00	45.00	23.74	5.36	88	18.00	43.00	23.35	4.34
BH (cm)	123	149.00	190.00	163.17	7.64	88	156.00	190.00	173.66	7.30
RL	120	23.00	31.00	27.38	1.59	83	24.00	33.50	29.35	2.15
UL	52	25.00	31.00	28.20	1.44	32	26.00	34.00	30.44	1.66
HL	120	21.00	38.00	29.17	2.94	82	23.00	39.00	31.13	3.58
CL	112	8.60	21.00	14.15	2.72	74	9.00	22.00	15.32	3.49

Table 3: Comparison of Difference of Variable in Females and Males of Right Upper Extremity**.**

Variables (cm)	Paired Differences					T	Df	Sig. (2-tailed)
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
BH (F)-BH (M)	-14.01	3.77	0.40	-14.81	-13.21	-34.85	87	0.000
RL(F)-RL(M)	-2.32	2.05	0.23	-2.77	-1.87	-10.21	80	0.000
UL (F)-UL(M)	-2.36	2.06	0.57	-3.60	-1.12	-4.14	12	0.001
HL(F)-HL(M)	-2.65	4.20	0.47	-3.59	-1.72	-5.66	79	0.000
CL (F)–CL(M)	-0.84	4.22	0.52	-1.87	0.19	-1.63	66	0.107

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Table 4: Pearson Correlation between BH with Right Upper Extremity Dimensions in the Overall Population.

Variables (cm)	Overall Population			Female			Males		
	N	Pearson Correlation	Sig. (2-tailed)	N	Pearson Correlation	Sig. (2-tailed)	N	Pearson Correlation	Sig. (2-tailed)
RL	203	0.635**	0.000	120	0.438**	0.000	83	0.608**	0.000
UL	84	0.822**	0.000	52	0.713**	0.000	32	0.713**	0.000
HL	202	0.393**	0.000	120	0.322**	0.000	82	0.257*	0.020
CL	186	0.004	0.953	112	-0.245**	0.009	74	0.038	0.751

**-Correlation is Significant at the 0.01 Level (2-tailed).
*-Correlation is Significant at the 0.05 Level (2-tailed).

Table 5: Constant, Regression Coefficient and Variation Explained (R^2) of Right Upper Extremity Variables with BH (Dependent) Variables in Overall Population.

Variables	Constant	Regression Coefficient	R^2	p value
RL	89.121	2.780	0.404	0.000
UL	61.105	3.604	0.676	0.000
HL	135.845	1.052	0.154	0.000

Table 6: Constant, Regression Coefficient and Variation Explained (R^2) of Right Upper Extremity Variables with BH (Dependent) Variables in Females and Males.

Variables	Females				Males			
	Constant	Regression Coefficient	R^2	p value	Constant	Regression Coefficient	R^2	p value
RL	104.976	2.126	0.192	0.000	114.451	2.018	0.369	0.000
UL	86.283	2.662	0.509	0.000	85.334	2.882	0.509	0.000
HL	138.551	0.844	0.104	0.000	157.930	0.500	0.066	0.020
CL	173.228	- 0.70	0.060	0.009				

Table 7: R^2, Adjusted R^2, and SEE of Right Upper Extremities Variables in Overall Population**.**

Variables	R	R^2	Adjusted R^2	SEE
RL	0.635	0.404	0.401	7.032
UL	0.822	0.676	0.672	4.693
HL	0.393	0.154	0.150	8.277

Table 8: R^2, Adjusted R^2, and SEE of Right Upper Extremities Variables in Females and Males.

Variables	Females				Males			
	R	R^2	Adjusted R^2	SEE	R	R^2	Adjusted R^2	SEE
RL	0.438	0.192	0.185	6.964	0.608	0.369	0.361	5.701
UL	0.713	0.509	0.499	3.799	0.713	0.509	0.492	4.778
HL	0.322	0.104	0.096	7.334	0.257	0.066	0.054	6.779
CL	0.245	0.060	0.052	7.572				

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Table 9: Regression Equations for Estimation of BH in the Overall Population Using Right Upper Extremity Measurements

Regression equation	±SEE
BH =89.121+2.780(RL)	7.032
BH =61.105+3.604(UL)	4.693
BH =135.845+1.052(HL)	8.277

Table 10: Regression Equations for Estimation of BH in Females Using Right Upper Extremity Measurements.

Regression equation (Female)	±SEE	Regression equation (Male)	±SEE
BH =104.976+2.126(RL)	6.964	BH =114.451+2.018(RL)	5.701
BH =86.283+2.662(UL)	3.799	BH =85.334+2.882(UL)	4.778
BH =138.551+0.844(HL)	7.335	BH =157.930+0.500(HL)	6.778
BH =173.228 - 0.70(CL)	7.572		

Table 11: Minimum, Maximum, Mean and Standard Deviations of the Predicted Values of BH by Regression Functions with Right Upper Extremity Variables in the Overall Population.

	Minimum	Maximum	Mean	Std. Deviation	N
Observed Value	149.00	190.00	167.55	9.10	211
RL	153.06	182.24	167.46	5.77	203
UL	151.21	183.64	165.82	6.74	84
HL	157.93	176.86	167.36	3.52	202

Table 12: Minimum, Maximum, Mean and Standard Deviations of the Predicted Values of BH by Regression Functions with Right Upper Extremity Variables in Females and Males.

Variables	Females					Males				
	Minimum	Maximum	Mean	Std. Deviation	N	Minimum	Maximum	Mean	Std. Deviation	N
Observed Value	149.00	190.00	163.17	7.64	123	156.00	190.00	173.66	7.30	88
RL	153.87	170.87	163.17	3.38	120	162.8783	182.05	173.67	4.34	83
UL	152.84	168.81	161.37	3.83	52	160.2648	183.32	173.06	4.78	32
HL	156.28	170.63	163.17	2.48	120	169.4222	177.42	173.48	1.79	82
CL	158.50	167.20	163.30	1.91	112					

Discussion

Close relationships exist between BH and dimensions of various body parts and the subsequent results are frequently applied in medico-legal investigation. In this study an attempt was made to establish BH using dimensions from long bones of the upper body extremity segments. Four right upper extremity measurements including BH of the subjects were measured. The prediction function was derived through linear regressions for each of the measurement with BH, for the overall population and for females and males separately. In this study, the mean BH and age for the population under study is 167.55 ± 9.00cm and 23.58 ± 4.95years respectively. While the minimum and maximum BH is 149.00 cm and 190.00 cm respectively. The mean BH and age for the female and male subjects are 163.17 ± 7.64cm, 23.74 ± 5.36 years and 173.66 ± 7.30cm and 23.35 ± 4.34 years respectively.

In sexing the upper extremity parameters, all the variables were highly significant (P< 0.0001) in most cases except the CL. These values were higher in the males than in the females. This agrees with most biological measurements for example: osteometry [18-19] Somatometry [8,14,20-24]; Cephalometry/Cephalofacial [25-29]. Distinct sexual dimorphisms have been reported in ulna measurements by many authors [30-35], ours study also considered UL and noted distinct sexual dimorphisms [36]. In their study investigated the use of height to ulna ratio measurement (height/ulna) in the estimation of stature and observed sexual dimorphisms.

Estimation of stature and determination of sex from radial and ulnar bone lengths in Turkish corpses has been reported by [37]. The sample composed of 80 males and 47 females with an average age of 36 and 30 years respectively. Lengths measurements from the radius and ulna were obtained by exposing the epiphyseal ends in fashion similar to dry long bones. Discriminant function statistics indicated sex determination accuracy as high as 96% while regression analysis was used in stature estimation from the two bones. Conclusively, the authors noted that in the absence of pelvis, sex could be determined from long bones and cranium as they have high accuracy in sexing.

A number of authors have investigated stature estimation based on measurements of the ulna and other bones of upper limb [19,38-40] and regression equations were generated; such generated equations must be population specific. [41], In their study estimated stature from upper extremity. The purpose of their study was to analyze the anthropometric relationships between dimensions of the upper extremity and BH. In their study of Turks residing in Istanbul, Turkey, 202 middle class males and 108 middle class females were sampled and variables such as hand length, forearm length and upper arm length were measured for analyses. They suggested that the estimation of a living stature could be made using the various dimensions of the upper limb while also stipulating that differences between populations must be considered before the application of their findings. This finding is in agreement with the present study because regression equations have been generated for the study population.

BH estimation based on UL in this study has SEE between 4.69-4.69 for the overall population, females and males while that of the other long bones (HL, RL and CL) of the upper extremity is between 5.70-8.28. This is however not similar to the standard errors of the estimations reported in several studies. For example, the standard errors of estimation from the formulae that [42] devised for several ethnic groups (whites, blacks, Mongoloids and Mexicans) based on humerus, radius, and ulna lengths were quite similar (approximately 4-4.8 cm). This may not be expected in our study due to ethnic variation and environmental factors.

In another study by [43], arm span was found to show the highest correlation with standing height. In the study, a cross sectional study was conducted to develop equations using several anthropometric measurements for estimating stature in Malaysian Elderly. The study used a total of 100 adults (aged 30-49 years) and 100 elderly subjects (aged 60–86 years) from three major ethnic groups of Malays, Chinese and Indians. Anthropometric variables utilized were body weight, height, arm span, half arm span, demi span and knee height. Although our study did not measure upper extremity spans; however the highest correlation was observed s in UL and this may not agree with the finding of [43], because correlation between arm span and stature has been reported to vary in different ethnic groups [44-45], The differential correlations may also arise due to different lengths of subsets of bones that constitute the arm span.

Mall G et al. [19] Investigated the determination of sex and estimation of stature from the long bones of the arm. The bones to be measured were prepared by mechanically removing soft tissues, tendons and ligaments. The study utilized a total of 143 individuals compromising of 64 males and 79 females who were sampled for variables including humeral length, vertical humeral head diameter, humeral epicondylar width, ulnar length, proximal ulnar width, distal ulnar width, radial length, radial head diameter, distal radial width. Their study revealed a significant difference between the means in males and females. Discriminant analysis had good results. Also the study showed that the linear regression analysis for correlation between bone lengths and stature led to unsatisfactory results with large 95% confidence intervals for the coefficient and high standard errors of estimate. The long bones in our study yielded satisfactory result with low SEE.

The estimation of stature is a very important step in developing biological profile for forensic identification [46,47]; because of this, the regression equations obtained in our study were checked for accuracy by comparing the estimated/predicted value of BH with the actual/observe BH. The results obtained were comparable.

Conclusion

This study has revealed that the UL in the overall population, females or males is the best upper extremity bone length that predicts the BH of the Igbos. Thus it is a veritable tool in forensic anthropology for estimation of BH and degree of sexual dimorphism.

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