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الجمعية العربية لعلوم الأدلة الجنائية والطب الشرعي
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Original Article

Stature Reconstruction from Percutaneous Anthropometry of Long Bones of Upper Extremity of Nigerians in the University of Lagos

استنباء طول القامة من خلال القياسات البشرية لعظام الأطراف العليا الطويلة لطلاب نيجيريين في جامعة لاغوس.

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Abstract

Anthropometric databases are essential in biological profiling. Stature reconstruction could play an integral role in helping forensic anthropologists in establishing the identity of human remains at crime and/or disaster scenes. This study aimed to derive simple and multiple linear regression equations for reconstruction of stature from upper limb segments in a living adult Nigerian population.

The sample included 230 adult medical students at the University of Lagos, Nigeria (100 males and 130 females), aged 18 to 36 years. Direct anthropometric methods were employed to measure all variables. Stature, arm and forearm lengths were measured.

Results showed a strong positive correlation between long bones and stature ($p < 0.01$). Both simple and multiple regression equations were derived and showed low standard errors of estimate and high coefficients of determination (R^2).

This study presents a simple and reliable approach to predict stature, which may help forensic scientists in disaster victim identification and in medico-legal jurisprudence.

Keywords: *Forensic Sciences, Stature Reconstruction, Long Bones, Upper Extremity, Adult Nigerians.*

المستخلص

تعد قواعد البيانات الأنثروبومترية ضرورية للغاية في التحديد النمطي الحيوي. ويمكن أن يلعب استنباء طول القامة البشرية دوراً أساسياً في مساعدة أخصائي الأنثروبولوجيا الشرعية في تضييق تحديد هوية الأشخاص الذين يتواجدون في مسرح الجريمة أو موقع الكارثة.

هدفت هذه الدراسة إلى اشتقاق معادلات انحدار خطي بسيطة ومتعددة لاستنباء طول القامة من أطوال أجزاء الأطراف العليا في السكان النيجيريين البالغين الأحياء.

شملت العينة المدروسة 230 طالباً وطالبة من كلية الطب بجامعة لاغوس في نيجيريا (100 من الذكور و130 من الإناث)، تتراوح أعمارهم بين 18 و36 سنة. واستخدمت أساليب القياسات البشرية المباشرة لقياس جميع المتغيرات. تم قياس طول القامة والساعد والذراع.

أظهرت النتائج معامل ارتباط قوي وإيجابي بين العظام الطويلة وطول القامة ($p < 0.01$). وأظهرت كل من معادلات الانحدار البسيطة والمتعددة المشتقة أخطاء قياسية منخفضة في التقدير ومعاملات ارتباط عالية في الإثبات (R^2).

تقدم هذه الدراسة مقاربة بسيطة لكنها موثوقة للتنبؤ بأطوال القامة، والتي قد تساعد علماء الطب الشرعي والأدلة الجنائية في تحديد هوية ضحايا الكوارث وفي القضايا الجنائية.

الكلمات المفتاحية: علوم الأدلة الجنائية، استنباء طول القامة، العظام الطويلة، الأطراف العليا، النيجيريون البالغون.

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1. Introduction

Disaster victim identification and biological profiling are conducted by experts using specific protocols developed after years of intensive training and experience. Nevertheless, standard approaches do not always meet the needs of certain crime or death scenes, especially when highly decomposed or skeletonized bodies are involved [1-2].

In many cases, the forensic expert is confronted with severe decomposition which may damage vital characteristics for the identification process such as facial attributes, fingerprints, eye and hair colour, scars, tattoos, etc. The remains can be affected by environmental conditions, fire, animals or even by the perpetrator to prevent positive identification [3-4].

Body segments have shown consistent ratios relative to the total body stature and these ratios between body segments are specific to age, gender, physical activity and population. This provides a baseline for human identification [5-9] which is an important element in all forensic cases [10]. In medico-legal investigations, identification of a person whether dead or alive is important as it helps in connecting the suspect to the crime [11-12].

Many characteristics can be used to identify a person's stature, which is considered a prime feature that can easily narrow down the unknown person's identity [13]. Stature reconstruction has immense anthropological importance when identifying the deceased using only a few body parts [14]. When a forensic expert is faced with a situation involving dismembered and fragmented body parts, vital questions such as the height, gender, and race of the victim become imperative for the purpose of unraveling the true identity of the deceased [15].

There is a lot of research on different populations concerning stature reconstruction using different parameters such as length of long bones, spine, hand dimensions, metatarsal lengths, skull, and scapula, etc. [16-19]. Those research mainly concentrated on Asian and Middle Eastern populations. The conclusions made from those studies have clearly stated that the derived regression equations are population-based and cannot be applied when reconstructing stature in other populations. Therefore, population specific studies are necessary for deriving population specific regression equation for stature reconstruction. In Nigeria, there is still a paucity of forensic anthropological data even with the increasing rate of man-made disasters like bombings, road traffic accidents, politically influenced assassinations and more recently, flooding. To this end, it has become necessary for regression formulae to be documented which will serve as reference points. Hence, the present study on stature reconstruction from percutaneous long bones of adult Nigerian medical students at the University of Lagos was carried out.

2. Materials and Methods

2.1 Ethical Approval

In order to carry out this study, ethical approval was obtained from the Health Research and Ethics Committee of the College of Medicine of the University of Lagos (CMUL). The approval was communicated via a memo: CM/HREC/12/16/083.

2.2 Informed Consent

A signed informed consent was obtained from for all participants. First, the procedure for measurement, purpose for the research and possible personal benefits were explained to the participants through information contained in the official informed consent document. All participants received a guarantee of respect and preservation of their personal information, anonymity throughout the measurements and the right to withdraw, if so desired, at any stage for any reason.

2.3 Study Design

The present study sample comprises 230 (100 males and 130 females) undergraduate and post-graduate medical students of Nigerian origin at the University of Lagos, Nigeria. The age group selected was between 18 to 36 years and participants were apparently healthy without any form of obvious congenital standing inability or upper limb deformities. Measurements were taken at a fixed time to avoid diurnal variations. Sampling variables included gender, age, ethnicity, stretch stature, arm length and forearm length.

2.4 Equipment Used

(1) Stadiometer: SECA alpha® model 770, Germany.

(2) Segmometer: The anthropometry segmometer used was constructed from a non-stretchable tape calibrated in centimeters by the investigators.

2.5 Anthropometric Measurements

Five anthropometric measurements (stature, left and right arm lengths, left and right forearm lengths) were taken according to the protocols recommended in the International Standards for Anthropometric Assessment published by the International Society for the Advancement of Kinanthropometry (ISAK) [41].

2.5.1 Marking of anatomical sites

Marking was done based on anatomical sites recommended by ISAK [41]. The following anatomical sites were marked:

Vertex: The most superior point on the skull in the mid-sagittal plane when the head is held in the Frankfort plane.

Acromiale: The point at the superior and external border of the acromion process when the subject is standing erect with relaxed arms.

Radiale: The point at the upper (proximal) and lateral border of the head of the radius.

Radial Styloid: A projection of bone on the lateral surface of the distal radius bone.

2.5.2 Stretch stature measurement (SS)

Measurement of stature was taken with a standard calibrated stadiometer. The measurement was taken by making the subject stand barefooted and erect on a horizontal resting plane of the stadiometer, having the palms of the hands turned inwards and the fingers pointing downwards after inhalation. The stature was measured as the vertical distance from the vertex to the floor of the stadiometer on a barefooted person.

2.5.3 Measurement of forearm length (FAL)

FAL was measured as the distance from the radiale to the radial styloid (Radiale – radial styloid).

The elbow was flexed to angle 90 degrees and the orientation of the segmometer was such that it parallelled the long axis of the radius (Figure-1).

Figure 1- *Measurement of Forearm Length (distance from the radiale to the radial stylion) using a segmometer.*

2.5.4 Measurement of arm length (AL)

AL was measured as the distance from the acromiale to the radiale (Acromiale - radiale).

The subject stood erect with the arms at the sides, palms against the thighs while measurements were taken (Figure-2).

Figure 2- *Measurement of arm length (distance from the acromiale to the radiale) using a segmometer.*

2.5.5 Statistical analysis

All data were analyzed using Statistical Package for Social Sciences (SPSS) software version 20, Chicago Inc. Descriptive statistics was done and presented as mean±SD. Pearson's moment correlation coefficients (r) were analyzed to know the relationship between stature and long bones of the upper limb. Scatter plots showing regression line were analyzed using Microsoft for Windows 7. Simple and multiple regression models were derived to reconstruct stature using Durbin Watson enter and stepwise method. Independent sample t-test was also employed to ascertain sexual dimorphism ($p < 0.01$).

3. Results

Table-1 shows the results of the descriptive statistics and independent sample test, respectively, between the male and female young adult Nigerians. The mean value for stature was recorded as 176.36 cm and 164.38 cm for males and females, respectively. The average left forearm length was 29.26 cm and 29.58 cm for the males and 26.62 cm and 27.01 cm for the females. Results of arm length for left and right upper limbs for the males were 33.057 cm and 33.52 cm, respectively, and for females 30.63 cm and 31.03 cm, respectively. It was observed that stature recorded higher values in males than females. These values were also observed to be directly proportional to the percutaneous measurements of long bones of the upper limb (Left and Right Forearm and Arm length) in the males and females. This also shows that long bones exhibit a statistically significant difference ($p < 0.01$) between males and females with higher values regularly seen among males than females for a similar age group.

Table-2 presents results of Pearson's moment correlation coefficient (r) between stretch stature and percutanous long bones of upper limbs in the male and female samples. The two long bones showed positive significant ($p < 0.01$) correlation with stature. This data presents stronger correlation coefficient (r) in forearm length (LFAL) than the arm in both sexes, as 0.80 and 0.79 was seen for the male left and right forearm length, respectively, while the female lengths were 0.74 and 0.76 left and right forearm, respectively. The relationship showed 0.75 and 0.72 for the male left and right forearm lengths while the female data showed 0.69 and 0.70 for left and right arm lengths, respectively.

Stature reconstruction regression equations were derived using the regression formula as follows:

Y=mx+c (Table-3 and 4) where y is the dependent variable (DV), m is the regression coefficient (slopes of the

Table 1- *Summary of descriptive and inferential statistics of long bones percutaneous anthropometry of left and right side of upper limb (cm) in males and females.*

Measured Parameters	Males n=100		Females n=130		Mean Diff	p-value
	Mean±SD	Min-Max	Mean±SD	Min-Max		
SS	176.36±8.13**	158.5-191.2	164.38±6.62**	148-178.70	11.97	0.00
LFAL	29.262±1.6316^{cc}	25.00-34.90	26.62±1.51^{cc}	23.00-30.80	2.57	0.00
RFAL	29.579±1.7141^{bb}	25.10-35.00	27.01±1.48^{bb}	24.00-31.40	2.64	0.00
LAL	33.057±1.7386^{aa}	29.20-38.20	30.63±1.83^{aa}	26.70-35.40	2.62	0.00
RAL	33.522±1.780^{dd}	29.00-38.60	31.03±1.87^{dd}	26.80-35.80	2.89	0.00

Values with similar superscript are statistically significant at $p < 0.01$ showing differences between males and females.

SS; Stretch Stature, LFAL; Left Forearm Length, RFAL; Right Forearm Length, LAL; Left Arm Length, RAL; Right Arm Length.

Table 2- *Correlation coefficient (r) between stretch stature and percutaneous long bones of the upper limb of the left and right side in male, female and combined sample population.*

Parameters	Males n=100	Females n=100	Sig. (2-tailed)
	Pearson Correlation (r)	Pearson Correlation (r)	p - value
LFAL	0.80**	0.74**	0.01
RFAL	0.79**	0.76**	0.01
LAL	0.75**	0.69**	0.01
RAL	0.72**	0.70**	0.01

*** Positive Pearson moment correlation coefficient is significant at $p < 0.01$*

LFAL; Left Forearm Length, RFAL; Right Forearm Length, LAL; Left Arm Length, RAL; Right Arm Length.

linear lines of best fit) that corresponds to the independent variable (IV), and c is the constant, which is the intercept on the y axis.

Table-3 and 4 show results of Durbin Watson simple linear regression formulas for the male and female samples for both left and right limb segments. This is presented alongside the analysis of paired sample t-test between observed and predicted stature for both mean values and their ranges. This reveals any significant differences between measured and predicted stature. All the four equations derived from the present study record no statistical significant difference ($p < 0.01$) between measured and reconstructed stature.

Table-5 shows results of multiple regression equations for stature reconstruction using anthropometric parameters of left and right long bones of upper limbs studied in the males and females.

Figures-3-6 represent the scattered plots and simple lin-

Table 3- *Comparison of measured and reconstructed stature from simple linear regression formula of right and left upper limb long bones among males.*

Variables	Regression Equation	Observed Values		Predicted values		R^2	±SEE
		Mean±SD	Min-Max	Mean±SD	Min-Max		
RFAL	Y=(2.928×RFAL)+89.75	176.36±8.13	25.00-34.90	176.36±5.02	163.24-192.23	0.622	3.660
LFAL	Y=(3.094×LFAL)+85.81	176.36±8.13	25.10-35.00	176.36±5.05	163.17-193.80	0.640	3.705
RAM	Y=(2.490×RAM)+87.12	176.36±8.13	29.20-38.20	176.36±4.56	164.76-189.38	0.522	3.862
LAL	Y=(2.500×LAL)+87.82	176.36±8.13	29.00-38.60	176.35±4.58	166.34-188.23	0.586	3.865

Values with TT are statistically significant difference between measured and reconstructed mean stature at $p < 0.01$

LFAL; Left Forearm Length, RFAL; Right Forearm Length, LAL; Left Arm Length, RAL; Right Arm Length.

Table 4- *Comparison of measured and reconstructed stature from simple linear regression models of right and left upper limb long bones among females.*

variables	Regression Equation	Observed Values		Predicted Values		R^2	±SEE
		Mean±SD	Min-Max	Mean±SD	Min-Max		
RFAL	Y=(3.407×RFAL)+72.36	164.38±6.62	23.00-30.80	164.38±5.05	154.12-179.33	0.662	3.788
LFAL	Y=(3.247×LFAL)+77.94	164.38±6.62	24.00-31.40	164.38±4.91	152.62-177.94	0.642	3.756
LAL	Y=(2.500×LAL)+87.82	164.38±6.62	26.80-35.80	164.38±4.58	154.56-176.31	0.592	3.887
RAM	Y=(2.490×RAM)+87.12	164.38±6.62	26.70-35.40	164.38±4.66	153.84-176.25	0.604	3.978

Values with PP have a statistically significant difference between measured and reconstructed mean stature at $p < 0.01$

Y; Dependent variable (Stature), RFAL; Right Forearm Length, RAL; Right Arm length, LFAL; Left Forearm length, LAL; Left arm length, R2; Coefficient of determination, SEE; Standard Error of Estimate.

ear equations of stature reconstruction from left and right side percutaneous long bones in male and female cases with various levels of precision as observed in coefficients of determination (R^2). The higher the R^2 value in the equation, the more precise the outcome of reconstruction could be.

Table 5- *Multiple regression equations for stature reconstruction using anthropometric parameters of right and left long bones of upper limb among males and females.*

Male Sapmle	Regression Equation	±SEE	R^2
RFAL and RAL	Y=(2.13×RFAL)+(1.025×RAL)+78.79	3.660	0.70
LFAL and LAL	Y=(2.54×LFAL)+(0.753×LAL)+77.16	3.705	0.68
Female Sapmle	**Regression Equation**	**±SEE**	**R^2**
RFAL and LAL	Y=(2.359×RFAL)+(1.319×RAL)+59.73	3.862	0.67
LFAL and LAL	Y=(2.227×LFAL)+(1.368×LAL)+63.21	3.865	0.64

Values with PP have a statistically significant difference between measured and reconstructed mean stature at p < 0.01
Y; Dependent variable (Stature), RFAL; Right Forearm Length, RAL; Right Arm length, LFAL; Left Forearm length, LAL; Left arm length, R2; Coefficient of determination.

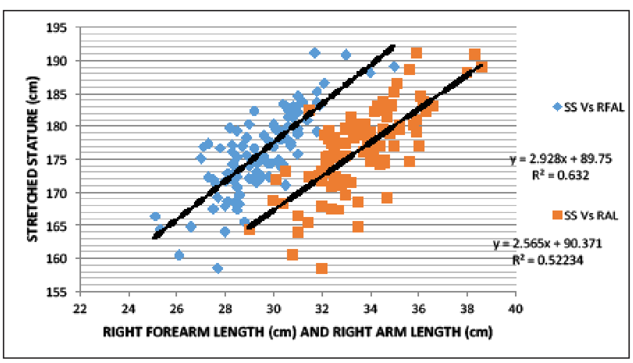

Figure 3- *Scatter plot of stretched stature (cm) vs right forearm length (cm) and right arm length (cm) in males.*

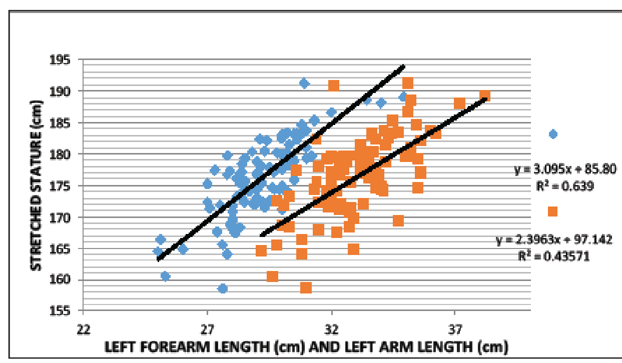

Figure 4- *Scatter plot of stretched stature (cm) vs left forearm length (cm) and left arm length (cm) in males.*

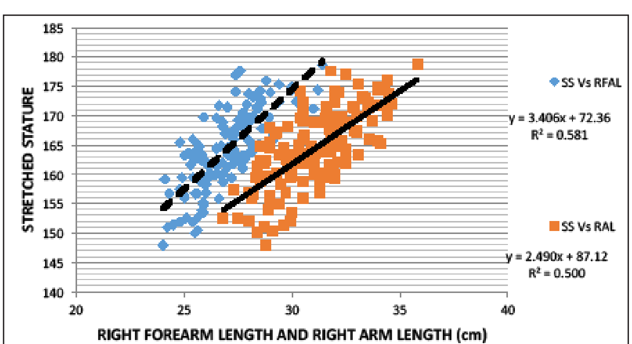

Figure 5- *Scatter plot of stretched stature (cm) vs right forearm length (cm) and right arm length (cm) in females.*

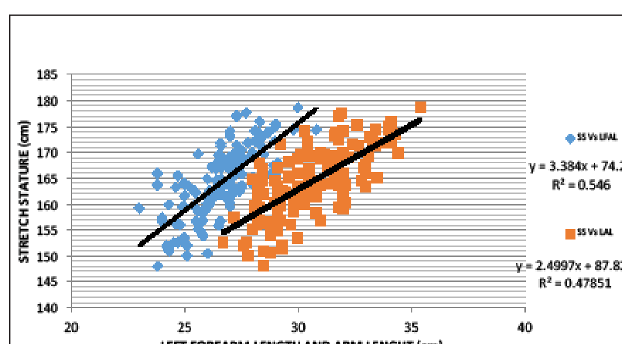

Figure 6- *Scatter plot of stretched stature (cm) vs left forearm length (cm) and left arm length (cm) in females.*

4. Discussion

Estimation of stature from long bones of upper extremity has been investigated extensively by different authors, whose findings have all attested that the parameters (arm and forearm lengths) are reliable and accurate determinants of human stature [16, 20-24]. The present study investigated a previously unstudied adult Nigerian population in the University of Lagos. This study was an attempt to provide a database for a Nigerian adult population by providing regression equations that are particluar to people of Nigerian decent. This database may be used whenever stature reconstruction is needed as a means of human identification in cases of disaster for victim identification and biological profiling [3, 25].

The present study showed statistically significant differences ($p < 0.01$) between males and females in both forearm length and arm length. This corresponds with the differences in their average stature, which is higher in males than females. These results are in conformity with the work of Borkar [26] and Ahmed [27]. They reported that taller people tend to possess longer limbs than their shorter counterparts. They further speculated that males were observed to be taller than females, which is in tandem with the present results.

The results of the present findings observed strong correlation coefficient between stretch stature and long bones of the upper extremity, when compared to the work of Chikhalkar et al. [20] on estimation of stature from measurements of long bones among the Mumbai population. They found strong correlation between stature and forearm length of (r = 0.6558) with positive significant correlation at ($p < 0.01$), but the r-value was lower than the result of the present study. They derived a regression equation for stature estimation as follows: Y= 86.772654 + 2.997967 * X). It is observed that both their correlation coefficient (r) and the simple linear equation are different from the results obtained in this study. The results of the present study contradict the correlation coefficient of forearm length published by Akhlaghi et al. [16] in an Iranian population, which documents very weak correlation in males (0.354) and in females (0.299). Their prediction equation was S = (FAL× 1.886) +107.344 and (FAL× 1.489) +132.83 for males and females, respectively, which is not similar to the one obtained in the present study. Sharaf El-Din et al. [28] derived the following equations for stature estimation from forearm length in an Egyptian population: S=126.07+1.661x (FL) in males and S=133.3+1.11x (FL) in females with low standard error of estimates (SEE) of 3.20 in males and 3.43 females. This was similar to the low values in this study. Such findings further strengthen the previous claims that long bones are reliable in stature estimation with lower chances of errors due to low SEE and high coefficients of determination.

Malay et al. [7] predicted height from ulnar length among females in the Burdwan district of west Bengal and found a very strong positive correlation (0.82 for the left hand and 0.67 for the right ulna length) with standard error of estimates of 3.59 for the left ulna length and 4.68 for the right ulna length. This is in tandem with the submission made by other authors that long bones are good and reliable pointers of stature reconstruction. [3, 29, 30, 37-39]

Arm length showed strong and positive correlation with stature. This agrees with the findings of Navid et al. [22], who studied Tehran medical students and documented a correlation coefficient of (r =0.716, at $p < 0.001$). Their study also recorded different linear regression formulae for stature estimation from upper arm length in the total sample with a SEE of 3.16 and coefficient of determination (R^2) value of 0.513, respectively. The male cases recorded 4.520 and 0.398 for SEE and R^2 values, respectively, while the female cases recorded SEE and R^2 values of 4.32 and 0.435, respectively Their results showed higher SEE in males than females and lower R^2 values in males than females, which is similar to the results of the present study. This connotes that the regression models derived for stature reconstruction from this study could be more reliable than the report of Navid et al. [22] because the lower the standard error of estimates the higher the chances of accuracy [20, 31-38]. Akhlaghi et al. [16] also predicted stature in an Iranian population using arm length. They reported a lower Pearson moment correlation coefficient (r) of 0.602 in males and 0.669 in females followed by regression equations S=(AL×1.886) +107.344 to predict male stature and S= (AL× 1.911) + 98.099 to predict female stature, which were not similar to the equations derived from this study to reconstruct stature.

Borker [26], while studying the western region population of Maharashtra, India, also reported strong positive Pearson's correlation in males of 0.852 and 0.849 for the left and the right arm lengths, respectively, while the females' correlation values were 0.801 and 0.793 for the left and right arm length, respectively, with a positive statistically significant *p*-value less than 0.05. This conforms with the present report with Pearson's correlation coefficient (r) in table 2. Both their study and the current research recorded strong and positive correlation, but the present results had 99% confidence level ($p < 0.01$). Mahakizadeh et al. [33] also recorded a strong correlation coefficient of 0.89, similar to that that obtained in the present study. But irrespective of the similarities, regression equations derived from their work on estimation of stature from arm length measurements among Iranian adults are population-specific. The formulas derived by Mahakizadeh et al. [33] cannot be used to predict stature in Nigerian adults, even though the two studies recorded low standard error of estimates and high coefficients of determination.

Mall et al. [19] presented a contrary view in their report on German population, with 95% confidence intervals for the correlation coefficients and high standard errors of estimate (S.E.E). Thus, they concluded that their linear regression analysis for quantifying the correlation between the bone lengths and stature were not reliable. Dorjee and Sen [23] further estimated stature from arm span, arm length and tibial length among a Bengalese population. They reported correlation coefficient r = + 0.828, $p < 0.01$ for males and r = + 0.970, $p < 0.01$ for females. They also recorded very low SEE values of 2.809 and 2.861 for male and female arm lengths, respectively.

Even the findings of Barbosa et al. [40] on English and Portuguese populations found that no two populations have exact values for stature and upper limb segments. They derived contrasting correlation coefficients and regression equations from the two populations they studied in an attempt to estimate stature from ulna length. Their results do not match with the current study because of discrepancies in population.

Forensic studies are useful in human identification, especially when mutilated and dismembered body parts are found at crime scenes. In addition, establishing the true identity of victims of natural or man-made disasters is essential. Therefore, the derived regression equations from the present study may be of relevance in reconstructing stature, which is a vital attribute in human identification.

5. Conclusion

Reconstruction of stature from long bones of the upper extremity is of great medico-legal relevance. This study recorded a strong relationship between stature and long bones of the upper limb segments. Eight simple linear regression equations and four multiple linear regression formulas derived in this study reliably reconstructed stature in an adult Nigerian population. There was no statistically significant difference ($p < 0.01$) between the measured and predicted mean stature. Therefore, these equations are reliable tools to predict stature in a Nigerian population. The application of these regression models in other populations might provide incorrect prediction results. It is hoped that the derived formulae will help in forensic identification when only partial remains are found.

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Conflict of interest

None.

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