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Original Article

A Study of Bilateral Asymmetry of Upper Extremities and its Effects on Stature Reconstruction amongst Nigerians

دراسة عدم التماثل الثنائي في الأطراف العلوية وتأثيراته على إعادة بناء القامة لدى النيجيريين

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Abstract

The relevance of stature prediction from body segments to a forensic scientist cannot be overemphasized. But the presence of bilateral asymmetry between these limbs still poses a lot of challenges in ascertaining accurate values from estimates. A regression equation derived from the right side and applied to the left side may cause more harm than good in medico-legal investigations. The aim of this study is to predict stature from limb lengths and to investigate the effect of bilateral asymmetry on stature reconstruction.

A total of 230 healthy Nigerians (100 males and 130 females) aged between 18 to 36 years were recruited for the measurement. Stature, left and right limb lengths were measured in centimeters in tandem with the standard anthropometric procedure. Statistical analysis was done using SPSS version 20 Chicago Inc.

Results of this study showed sexual dimorphism and bilateral asymmetry between left and right limb lengths in both sexes at a significance level of $p < 0.01$.

The present outcome may be found useful by Forensic anthropologist and anatomist in narrowing down human individuality using the regression models. Therefore, there is need for right appropriation of an equation to the correct side of the body otherwise it may lead to erroneous results.

Keywords: *Forensic Sciences, Stature Reconstruction, Limbs, Bilateral Asymmetry, Nigerians.*

المستخلص

لا يمكن المبالغة في التأكيد على أهمية التنبؤ بطول جزء من أجزاء الجسم بالنسبة لأخصائي الأدلة الجنائية. لكن وجود عدم التماثل الثنائي بين الأطراف لا يزال يشكل الكثير من التحديات في التحقق من القيمة الدقيقة لتقديرات شكل القامة. قد يؤدي تطبيق معادلة انحدار مستمدة من الجانب الأيمن من الجسم في الجانب الأيسر للجسم إلى ضرر أكثر من النفع في التحقيقات الطبية الجنائية. والهدف من هذه الدراسة هو التنبؤ بطول القامة من أطوال الأطراف ولرؤية تأثير عدم التماثل الثنائي على إعادة بناء القامة.

تم الدراسة على ما مجموعه ٢٣٠ من النيجيريين الأصحاء (١٠٠ من الذكور و١٣٠ من الإناث)، والذين تتراوح أعمارهم بين ١٨ إلى ٣٦ سنة. وتم قياس طول القامة وأطوال الأطراف اليسرى واليمنى بالسنتيمتر جنباً إلى جنب مع الإجراء الأنثروبومتري المعياري. وأجري التحليل الإحصائي باستخدام SPSS الإصدار ٢٠ Chicago Inc.

أظهرت نتائج هذه الدراسة مَثْنَوِيَّةُ الشَّكْلِ الجِنْسِيَّة وعدم التماثل الثنائي بين أطوال الأطراف اليسرى واليمنى لدى الجنسين وبقيمة دلالة P <٠,٠١.

وقد تلعب النتائج الحالية دوراً مفيداً في عمل أخصائيي الأنثروبولوجيا الجنائية والتشريح في تضييق الاحتمالات لتحديد الهوية باستخدام نماذج الانحدار. ولذلك، هناك حاجة إلى الاعتماد السليم في تكوين المعادلة على الجانب الصحيح من الجسم وإلا قد يؤدي ذلك إلى نتائج خاطئة.

الكلمات المفتاحية: علوم الأدلة الجنائية، الأطراف، إعادة بناء القامة، التباين الثنائي، النيجيريين.

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1. Introduction

Reconstruction of stature is an important parameter in the identification of dismembered, commingled, mutilated bodies and skeletal remains in forensic examination. [1] Bilateral asymmetry is defined as the difference between the measurements of the left and right sides of the human body [1].

A forensic investigator is usually asked to comment and probably proffer solution on the individuality of the deceased whenever case material, whether skeletal remains or body parts, are brought for identification. The need for identification may arise in cases of mass disaster such as terrorist attacks, wars, plane crashes, road and train accidents, and most recently flooding and earth quakes [2-5].

The cause of bilateral asymmetry in the body is not known fully [5-6]. Some researchers have suggested that bilateral asymmetry may develop in the prenatal stage and continue until reaching adulthood [2, 6-10]. However, some are of the opinion that the development of bilateral asymmety in the body dimensions occurs without influence of a preference for one side of the body in movement [11].

It is also suggested that fetal environmental factors such as nutritional, physiological and diseases may also be responsible for the development of bilateral asymmetry because they may collapse the genetic linkage system that controls bilaterall symmetry of the human body [1, 12].

Kanchan and Kumar [12] further explained the presence of bilateral asymmetry in the limbs on the grounds of more stress and strain experienced by the dominant side of the body.They referred to this as directional asymmetry, as the preferred side is used more often for physical activities than the other.

Several studies have noticed the presence of skeletal and morphological asymmetries in the human body throughout different periods of history. Some studies have focused on bilateral asymmetry in the living [7-10], while others have been conducted on long bones of extremities in corpses. These studies demonstrated the existence of bilateral asymmetry in the anthropometric dimensions, bones, dermatoglyphic patterns, rate of maturation or growth of the skeletal components, and various characters of the skull bone, face and so on [11, 13-16]. These variations have been demonstrated in embryos, fetuses, infants, children, adolescents, and in adults [12, 17-18].

It is obvious that reliable regression formulas are good markers in human identification, provided the proper equation is appropriated and applied to the correct side of the body and population. When an equation is formulated from one side of the body or population and is used for another side or population, it usually results in incorrect prediction.

Therefore, it has become pertinent for reference data to be documented for the reconstruction of stature using upper limb lengths among Nigerian adults, regardless of their ethnic affiliations. There is a need to emphasize researchers to consider the presence of bilateral asymmetry and cationed them that the equation derived from right side of the body is not used for the left side. Thus, the present study was undertaken to tackle the aforementioned issues.

2. Materials and Methods

2.1 Study Design

The present study was conducted on a sample of 230 adult Nigerians (100 males and 130 females) aged between 18 to 36 years. Participants recruited for the measurement exercise were undergraduate and postgraduate medical students of the University of Lagos, which is a cosmopolitan

institution representing mixed Nigerian ethnic groups. Subjects with upper limb deformities or impairments that may hinder standing ability were excluded from this study. Measurements were taken at a set and regular time to avoid the effect of diurnal variation [19]. The first author took all the anthropometric measurements to avoid inter-observer bias error and a data normality test was conducted by the second author.

2.2 Ethical Clearance and Patient's Informed Consent

Prior to the commencement of data collection, a proposal was presented to the health research and ethics committee of the College of Medicine, University of Lagos. Thereafter, a memo with reference number: CM/HREC/12/16/083 was communicated to the principal investigator regarding the approval of the work to be conducted. The participants were given informed consent documents, followed by oral explanation of the study objectives and possible benefits. Participants were asked to sign the document expressing their consent.

2.3 Measurements

Non-stretchable Anthropometric tape (Lufkin specialty Executive® Diameter flexible steel measuring tape model W606PM. Seca Stadiometre Germany Inc.) calibrated in centimeters was used in this study.Direct anthropometric method was employed according to the protocols recommended in the International Standards for Anthropometric Assessment published by the International Society for the Advancement of Kinanthropometry [20].

2.3.1 Stature

Stature measurements were recorded with the help of a Seca Stadiometer calibrated in centimeters. Stature was measured as the vertical distance between the vertex and the floor of the anthropometer on a barefooted person.

2.3.2 Anthropometric protocol

The participants were made to assume an erect position with the head at Frankfurt plane (eye-ear level), hands besides the thighs and the back in contact with the stadiometer. Then the upper sliding bar of the anthropometer was made in contact with the vertex followed by measurement (Figure-1).

Figure 1- *Stature was measured as the vertical distance between the vertex and the floor of the anthropometer on a barefooted person.*

2.3.3 Limb length

This was measured as the distance between the acro-

miale and the dactylion, with the use of a non-stretchable tape calibrated in centimeters.

2.3.4 Anthropometric protocol

The subjects were made to stand erect with their hands besides the thighs, and then a non-stretchable tape was placed between the acromiale and dactylion. One end of the tape was firmly held by a research assistant while measurements were taken at the other end (Figure-2 and 3).

2.3.5 Statistical analysis

The collated data was subjected to a series of statistical analyses using SPSS version 20 Chicago incorporated. The statistical tools employed in this study included: descriptive and inferential statistics, Independent sample t-test, Paired sample t-test, Pearson product-moment correlation coefficient and Durbin-Watson regression model.

Figure 2- *Left Limb Length was measured as the distance between the acromiale and the dactylion, with the use of a non-stretchable tape calibrated to centimeters.*

Figure 3- *Right Limb Length was measured as the distance between the acromiale and the dactylion, with the help of a non-stretchable tape calibrated to centimeters*

3. Results

The results of descriptive statistics of stature and upper limb lengths measurements in adult Nigerian males, females and combined sample population for left and right limb length are presented in Table-1. A statistical significant difference ($p < 0.01$) was seen between males and females with greater results observed in males.

Table-2 presents result of bilateral differences (right-left) in the limb dimensions. Maximum bilateral asymmetry was seen in males, whereas the female variables showed the least level of bilateral asymmetry. The results were analysed using 99% confidence interval of the difference.

The outcome of Pearson's product-moment correlation coefficients showed a strong positive correlation ($p < 0.01$), in all parameters studied. Males, females and combined

Table 1- *Summary of the descriptive statistics of age, stature and digit lengths in males, females and the combined sample.*

Variables	Males n = 100		Females n = 130			Combined Sample n = 230	
	Mean±SD	Min-Max	Mean±SD	Min-Max	p - Value	Mean±SD	Min-Max
Ages (years)	20.48±3.18	17 - 36	19.75±2.87	17 - 34	0.09	20.07±3.02	17 - 36
SS (cm)	176.36±8.13aa	158.5-191.2	164.38±6.62 aa	148-178.70	0.00	169.59±8.79	148-191.20
LLL (cm)	82.17±3.96dd	71.90-95.60	75.39±3.77 dd	67.90-85.80	0.00	78.24±5.17	67.60-95.60
RLL (cm)	83.23±4.13cc	73.30-96.40	76.47±3.75 cc	68.70-87.80	0.00	79.29±5.24	68.40-96.40

Values with similar superscripts statistically significant different at $p < 0.01$ between males and females.

SD, Standard deviation; SS, Stature; Min, Minimum; Max, Maximum; RLL, Right limb length; LLL, Left limb length; n, number of samples.

Table 2- *Bilateral asymmetry between left and right hand in males, females and combined sample.*

Paired Samples t-Test						
	Paired Differences					
	Mean Difference±SD (right-left)	99% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
		Lower	Upper			
Males RLL - LLL	1.05±1.13	0.83	1.28	9.33	9917 - 34 0.09	0.000
Females RLL - LLL	1.03±0.78	0.89	1.17	15.06	129	0.000
Combined Sample RLL – LLL	1.04±0.95	0.92	1.16	16.69	229	0.000

Values with 2-tail significant <0.01 is statistical different between left and right hand.

RLL, Right limb length; LLL, Left limb length; n, number of samples; t, differences in mean; df, degree of freedom; Sig.2-tailed, two tailed significant difference.

samples showed strong association with stature (Table-3).

Table-4 depicts analysis of Durbin-Watson simple linear regression equations showing minimum, maximum and mean predicted stature in the left and right upper limb lengths in males, females and a combined sample. Considering the results of minimum and maximum values derived, right limb length produced more reliable equation in males; meanwhile, whereas in females left limb length formulated a more accurate formula which is similar to the outcome of the combined population.

The comparison and effect of bilateral asymmetry on stature reconstruction, when the mean values of upper limb length on the right side were tested using regression equations derived from the left side, is given in Table-5. This re-

Table 3- *Pearson's product-moment correlation coefficients (r) between Stature (cm) and left and right limb lengths (cm) in male, female and combined sample.*

Variables (cm)	Pearson Correlation Coefficients (r)		
	Males (*n* = 100)	Females (*n* = 130)	Combined Sample (*n* = 230)
	Coefficient (r)	Coefficient (r)	Coefficient (r)
LLL/S	0.824**	0.831**	0.907**
RLL/S	0.851**	0.864**	0.932**

**. *Correlation is significant at the 0.01 level (2-tailed).*

RLL, Right limb length; LLL, Left limb length; n, number of samples.

Table 4- *Simple linear regression equation for stature reconstruction from left and right upper limb length in male, female and combined sample.*

Males	Regression Equation	±SEE	R^2	Min. Predicted	Max. Predicted	Mean±SD
LLL	S=1.328×LLL+67.196	3.514	0.693	162.7071	194.1900	176.3550±5.25
RLL	S=1.286×RLL+69.30	3.426	0.708	163.5847	193.2980	176.3550±5.311
Females	**Regression Equation**	**±SEE**	**R^2**	**Min. Predicted**	**Max. Predicted**	**Mean±SD**
LLL	S=1.459×LLL+54.604	3.699	0.690	153.260	179.822	164.382±5.503
RLL	S=1.478×RLL+51.657	3.562	0.713	152.774	181.453	164.382±5.590
Combined Sample	**Regression Equation**	**±SEE**	**R^2**	**Min. Predicted**	**Max. Predicted**	**Mean±SD**
LLL	S= 1.544×LLL+48.818	3.707	0.823	153.158	195.789	169.588±7.977
RLL	S=1.531×LLL+48.209	3.613	0.832	152.923	196.377	169.588±8.019

SEE, Standard Error of Estimate; R^2, Coefficient of determination; Min. Predicted, Minimum predicted stature; Max. Predicted, Maximum predicted stature.

Table 5- *Comparative analysis and effect of asymmetry on stature estimation when mean values of upper limb length on the right side were tested using regression equations derived for the left side.*

Regression Equation from left limb length	Mean stature predicted from left limb mean value	Mean stature predicted from right limb mean value	Mean Difference	*p* -Value
Males				
S=1.328×LLL+67.196	176.32	177.72	1.404	0.00
Females				
S=1.459×LLL+54.604	164.57	166.17	1.604	0.00
Combined Sample				
S=1.544×LLL+48.818	169.62	171.24	1.62	0.00

Statistically significant different between mean predicted stature from left and right using left limb length at $p < 0.01$.

sult summarizes the study, showing the analysis of paired sample t-test. Statistically significant difference ($p < 0.01$) was observed between the mean predicted stature from the left side of the body and when the left equation was applied to the right limb length.

4. Discussion

With or without the presence of bilateral asymmetry in limb segments, forensic scientists have been presenting different approaches to provide alternatives that will aid medico-legal practitioners in crime investigation or disaster related situations. Numerous researchers who have attempted to unravel the true cause of asymmetry that exist between two sides of the body have not provided sufficient evidence to ascertain the exact cause of bilateral asymmetry [1-5]. Several factors (change in pattern with age and sex, environment, occupation etc.) have been considered as key players in determining the cause of bilateral asymmetry [13-18].

Individuals who are involved in hard physical work and use agricultural equipment for a long time may result in the development of increased musculature and consequently increased growth of the bones on one side of the body [1]. Therefore, the level of bilateral asymmetry in a human body is strongly associated to the nature of work the person does [1, 21]. In addition, Kannus et al. [22] and Little et al. [23] reported that marked asymmetry is found to be associated with massive unilateral engagement.

This study presents the results of descriptive and inferential statistics for males, females and combined population, alongside with the outcome of independent samples t-test, which showed great levels of sexual dimorphism ($p < 0.01$) with higher values regularly seen among the male cases in conformity with the results of Kujanova et al., [24] that derived significant higher values in males than females in central Europe.

The results of paired sample analysis documented that there exists a statistically significant difference between left and right mean values of limb length in males, females and combined cases with 99% confidence interval level. These results suggest that although the opposite sides of the body look alike, they do not have the same proportions. Because of this discrepancy in proportions, erroneous result will occur if an equation formulated from one side of

the body is applied for another.

The current study reports strong positive significant ($p < 0.01$) correlation coefficient between stature and upper limb length in the Nigerian male, female and combined population. This strong and positive association between upper limb length and stature implies that the two variables have a direct and proportionate influence on each other. Hence, there is a high possibility of deriving the regression formulas to predict stature from these limb measurements with reliability.

The regression equations formulated from this study showed low values for standard error of estimate (SEE) and high coefficient of determination (R^2), which are two major indicators that show the reliability of an equation. The minimum and maximum predicted stature derived from left and right limb dimensions did not record the same values, which highlights the differences that exist between two sides of the body.

When the mean values of the right side are used in the regression equations derived for the left side limb length, a significant difference ($p < 0.01$) is observed in the predicted stature. The statistical significant differences observed in predicted stature can be attributed to the significant bilateral asymmetry observed between upper limb lengths. Therefore, one can deduce that consistent higher values observed in the right hand in males, females and the combined sample is a result of hand dominance and the preferred frequent use of the right hand among the present population. This is similar to earlier results obtained by Krishan et al., [1] on right-handed adult male Gujjars of India who were predominantly farmers.

Kanchan and Kumar [12] proposed that bilateral asymmetry in the limbs is caused by more stress and strain experienced by the dominant side They refer to this as directional asymmetry, as the preferred side is used more often for physical activities. Their findings are in agreement with this study.

Kujanová et al. [24] also worked on medieval and recent populations of central Europe and found statistical significant difference in right and left limbs.

Several other works have offered different views about the presence of bilateral asymmetry; however, their findings and results concluded that no two parts of the body found on opposite sides are equal [2-12,25-30].

The present results found statistical significant difference ($p < 0.01$) between left and right limb lengths. This was further proven in the derived equations when the mean value derived from left limb length was substituted as the independent variable in the derived formula for the right side. The predicted stature was totally different from the value seen in the correct side. This was similar to what Krishan et al. [1] found in their results. This study noticed significantly ($p < 0.01$) greater values in right limb lengths in both sexes, which could be attributed to their right-handedness and performance rate, which causes more development on the right side than the left.

5. Conclusion

The current results indicate that statistically significant bilateral asymmetry exists in upper limb length of adult male and female Nigerian adults. The results of this study show that right-handed individuals have larger right hands. This asymmetry is due to right hand dominance and frequent activities performed by the right hand. Stature can be predicted from upper limb length accurately in situations associated with man-made or natural disasters that involves

forensic investigation due to presence of commingled and mutilated remains.

This study also found there is a possibility of getting false results while reconstructing stature from these statistically significant asymmetrical limb lengths. This occurs when an equation derived from one side is used on the other side. Therefore, while reconstructing stature from upper limb lengths, the forensic expert must first decipher the side of the body for appropriate application of the formulas.

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Conflict of Interest

None declared.

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