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Derivation of Regression Equations for Stature Estimation from Digit Lengths of Nigerian Medical Students in University of Lagos

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Abstract

Identification of an individual using stature is of great significance in forensic practice. With the increasing frequency of natural and man-made disasters, it has become imperative for forensic anthropologists to establish population-specific forensic reference standards. This study aimed to derive predictive equations for stature estimation using five digit lengths.

A sample of 230 medical students (100 male and 130 female) of Nigerian parentage aged 18 to 36 years was recruited for this research. Stature and digit lengths were measured following standard procedures, followed by statistical analysis using SPSS (Version 20 Chicago Inc).

Results showed an average stature of 176.36 ± 8.13cm, 164.38 ± 6.62cm and 169.59 ± 8.79cm for males, females and a pooled sample, respectively. Sexual dimorphism was observed to be statistically significant ($p < 0.01$) across all the measured parameters, with greater values consistently recorded in males. Pearson correlation (r) had a range of 0.40 to 0.63. The weakest r-value is seen in males and the strongest in females. Simple and multilinear regression equations derived showed different values of coefficient of determination (R^2) and standard error of estimate (SEE) at an accurate estimation rate of >99%.

Digits correlation with stature found in this study may be of great relevance in human identification.

Keywords: Forensic Sciences, Human Identification, Stature, Digits, Nigeria

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اشتقاق معادلات الانحدار بهدف تقدير طول القامة من أطوال أصابع طلاب الطب النيجيريين في جامعة لاغوس.

المستخلص

يعد التعرف على الأفراد باستخدام طول القامة ذو أهمية كبيرة بالنسبة لممارسة الطب الشرعي. ومع تزايد تواتر الكوارث الطبيعية والكوارث الناتجة عن الفعل البشري أصبح من الضروري أن يضع علماء الأنثروبولوجيا الجنائيون معايير مرجعية للسكان تساعد على الاستعراف خاصة بالطب الشرعي.

هدفت هذه الدراسة إلى اشتقاق معادلات تتنبأ بتقدير القامة باستخدام أطوال الأصابع الخمس.

وقد تم إجراء الدراسة من خلال عينة تتكون من 230 طالباً طبياً (100 من الذكور و 130 من الإناث) من والدين نيجيريين، وتراوحت أعمار الطلاب بين 17 و 36 عاماً. تم قياس طول القامة وأطوال الأصابع وفقا للإجراءات القياسية، تلاها التحليل الإحصائي باستخدام برنامج الحزم الإحصائية SPSS (النسخة 20، شيكاغو)

أظهرت النتائج الوصفية أن متوسط أطوال القامات يساوي 176.36 ± 8.13 سم و 164.38 ± 6.62 سم و 169.59 ± 8.79 سم للذكور والإناث والعينة المجمعة للجنسين على التوالي. وقد لوحظ أن الاختلافات الناتجة عن الجنس كانت ذات دلالة إحصائية حيث كان مستوى الدلالة الاحصائي يساوي (p <0.01) في جميع المعاييرالمقاسة، مع تسجيل قيم أكبر باستمرار في الذكور. وكان معامل ارتباط بيرسون (r) يتراوح بين 0.40 و 0.63، حيث كانت قيم (r) أقل عند الذكور وأكبر عند الإناث. وأظهرت معادلات الانحدار البسيطة والمتعددة المستمدة قيم مختلفة لمعامل التحديد (R^2) وقيم الخطأ المعياري للتقدير (SEE) عند معدل دقة في التقدير أكبر من 99٪. وقد تكون أطوال الأصابع المرتبطة بطول القامة المستنتجة في هذه الدراسة ذات أهمية كبيرة في تحديد الهوية البشرية.

الكلمات المفتاحية: علوم الأدلة الجنائية، الهوية البشرية، طول القامة، طول الأصابع، نيجيريا.

1. Introduction

Among various parameters used to establish human identity, individual's stature is an inherent characteristic, the estimate of which is considered to be important in cases like earthquakes, road traffic accidents, deliberate mutilation, flooding, etc., where only fragmentary or mutilated remains of unknown persons are recovered [1]. Estimation of stature from different dimensions has considerable forensic value, not only for identification of skeletal remains, but also in developing descriptions of suspects from evidence at the scene of a crime and in corroborating height estimates from witnesses [2].

Traditionally, standards developed from the study of documented skeletal collections have been used as a benchmark for predicting the key indicators of identity (stature, age and sex). This approach, however, is limited to some degree, as the most accurate results are achieved when standards are applied to the population from which they are derived [3]. The accuracy of this approach may be further limited by historical differences in stature. A research comparing measurements over the past one-hundred years concluded that secular changes, particularly in developed countries, has resulted in variations in stature [4].

Reconstruction of stature is one of the important aspects of various identification markers for establishing the identity of a person [5]. Under the circumstances where dismembered, decomposed or fragmentary skeletal remains are recovered, the stature of an individual may be estimated by adopting anatomical methods if the complete skeleton is available for examination or by following the mathematical models where measurement of a single long or short bone may serve the purpose because a strong relationship exists between skeletal elements and the stature [6]. This means that measurement of any bone or combination of bones reflects stature [7].

There is a strong body of literature demonstrating the existence of strong positive correlation between stature and percutaneous anthropometric parameters of the upper limb [8-14].

Syeda et al. [15], Oria et al. [16], Jianpin et al. [17], Sahar and Nashwa [18] and Jakhar et al. [19] have carried out studies on stature prediction from hand length in Bengali, Nigerian, Chinese, Egyptian and Indian populations, respectively. Very little is known about stature prediction using anthropometry of the digits in living populations. Though Jervas et al. [20], have estimated stature from digit length in an Igbo ethnic group of Nigeria, there is still a dearth of forensic data for stature prediction due to increased cases of natural and man-made disasters. Hence, the present study aimed to reconstruct stature from the five digit lengths of the right hand in a sample of Nigerian population, which will provide reference data for stature prediction in such occurrences towards effective forensic and medico-legal investigations.

2. Materials and Methods

2.1 Subjects and Study Design

This cross-sectional study was carried out among male and female medical students from the College of Medicine at the University of Lagos in the anthropometry laboratory of the Department of Anatomy. A total of 230 participants (100 male and 130 female) aged between 18 and 36 years were randomly selected. Participation was entirely voluntary, and the selection was limited to subjects of Nigerian origin by both parents across all the ethnic groups. Excluded from the study were left handed persons and those physically challenged with musculoskeletal and dermatological deformities that might affect the measurement of stature and digit lengths.

2.2 Ethical Approval and Informed Consent

Ethical clearance was acquired from the Health Research and Ethics Committee (HREC) of the College of Medicine of the University of Lagos. Approval was confirmed with reference number CM/HREC/12/16/083 and communicated to the principal investigator. Consent forms were prepared, which outlined the measurement procedures and the confidentiality of subjects' information, such that the appendage of the signature by the participants indicated full consent.

2.3 Materials

1. A Seca 220 Stadiometer (Germany) calibrated in millimeters with a measuring range of 60 – 200 cm was used for stature measurement.
2. A Vernier caliper (Sliding) (Mitutoyo, Japan) was used to measure digit length.

2.4 Methods

Direct protocols used in this study are those established by the International Society for the advancement of Kinanthropometry ISAK [21]. Each measurement was taken and repeated twice by one observer to avoid inter-observer error, and the mean value was recorded in the study anthropometric proforma.

2.4.1 Stretch Stature Measurement

The measurements were taken as the maximum vertical distance from the floor to the vertex of the head. Each participant was asked to stand bare-footed on the flat platform, maintaining an erect position with their heels, buttocks, back (upper part) and back of the head in contact with the scale. With the arms placed on the side of the thigh, the subjects were then instructed to inhale and hold a deep breath. Their head was held in the Frankfort horizontal plane, and this position was achieved when the line joining the orbitale to the tragion was horizontal or at right angles to the long axis of the body. The horizontal sliding bar was then positioned on the contact point of the vertex of the head, and stature was recorded in centimeters at the end of an inward breadth (Figure-1).

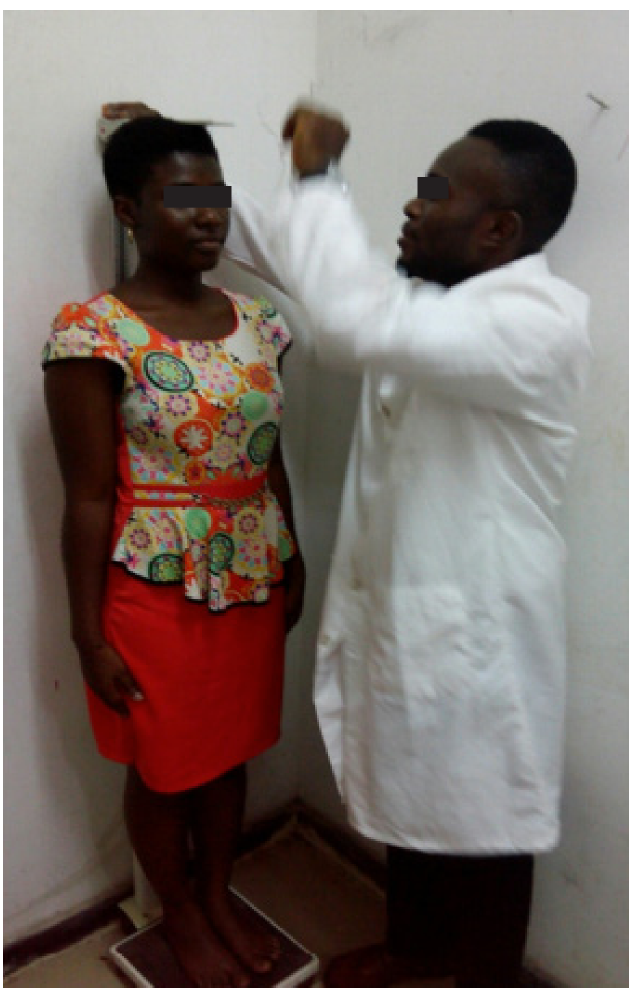

Figure 1- *Measurement of stretch stature from the vertex to the floor of the barefooted participant by stadiometer.*

2.4.2 Digit Lengths Measurement

The lengths of the five digits of the right hand were measured with the aid of a sliding vernier caliper from the ventral proximal crease to the dactylion of each digit. Where there was a band of crease at the base of the digit; the most proximal crease was used. The participants were asked to supinate their hands with the digit fully stretched. Then the sliding caliper was placed between the stipulated landmarks aforementioned (Figure-2)

Figure 2- *Measurement of right digit length from proximal flexor crease of the digit to the tip (dactylion) of the finger by sliding caliper.*

2.4.3 Statistical Analysis

The acquired data was analyzed using Statistical Package for Social Sciences (SPSS) software version 20 (Chicago Inc., USA) statistical tests included descriptive and

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

Variables (cm)	Descriptive and Inferential Statistics						
	Male (*n* = 100)		Female (*n* = 130)			Pooled Sample (*n* = 230)	
	Mean±S.D.	Range	Mean±S.D.	Range	*p* - value	Mean±S.D.	Range
Ages (Years)	20.48±3.18	18 - 36	19.75±2.87	18 - 34	0.08	20.07±3.02	18 - 36
SS	176.36±8.13**	158.5-191.2	64.38±6.62**	148-178.70	0.00	169.59±8.79	148-191.20
1DL	6.74±0.50dd	5.20-7.70	6.14±0.46dd	4.70-7.20	0.00	6.40±0.57	4.70-8.00
2DL	7.74±0.47cc	6.10-8.50	7.13±0.53cc	5.90-8.80	0.00	7.41±0.59	5.90-8.80
3DL	8.81±0.56xx	7.30-9.60	8.05±0.60xx	6.50-9.60	0.00	8.37±0.67	6.50-9.90
4DL	8.089±0.49aa	6.40-9.00	7.41±0.56aa	6.10-8.80	0.00	7.71±0.63	6.10-9.20
5DL	6.26±0.53ff	4.80-7.20	5.83±0.53ff	4.70-8.10	0.00	6.01±0.55	4.70-8.10

Values with similar superscript significant different at ($p < 0.01$) between males and females digit lengths

SS, Stretch stature; 1DL, First digit length; 2DL, Second digit length; 3DL, Third digit length; 4DL, Fourth digit length; 5DL, Fifth digit length; S.D., Standard deviation; n, number of participant.

Table 2- *Pearson's correlation coefficients (r) between Stature (cm) and five direct digit lengths (cm) in males, females and pooled Sample Population.*

Variables (cm)	Correlation Coefficients (r)		
	Male (*n* = 100)	Female (*n* = 130)	Pooled sample (*n* = 230)
	Coefficient (r)	Coefficient (r)	Coefficient (r)
1DL	0.45	0.54	0.65
2DL	0.60	0.63	0.71
3DL	0.58	0.63	0.73
4DL	0.61	0.62	0.71
5DL	0.40	0.52	0.53

Positive Pearson moment correlation coefficient (r) significant at ($p < 0.01$)

SS, Stretch Stature; 1DL, First digit length; 2DL, Second digit length; 3DL, Third digit length; 4DL, Fourth digit length; 5DL, Fifth digit length; n, number of sample.

Table 3- *Comparison between measured and predicted stature derived from simple linear regression models in Males using paired t-test.*

Hand Direct Digit Lengths (cm)	Paired *t*-test in Male Sample					
	Regression Equations	±SEE	R^2	Measured Stature (cm) Mean±S.D.	Predicted Stature (cm) Mean±S.D.	*p* - value
First digit Length (1DL)	S=144.7+(4.723×1DL)	5.871	0.143	176.36±8.13	175.35±4.42**	0.03
Second digit (2DL)	S=125.7+(6.531×2DL)	5.520	0.243	176.36±8.13	176.36±4.32	0.96
Third digit Length (3DL)	S=119.6+(6.440×3DL)	5.464	0.258	176.36±8.13	176.36±3.33	0.86
Fourth digit Length (4DL)	S=128.8+(5.867×4DL)	5.623	0.214	176.36±8.13	176.26±5.72	0.08
Fifth digit Length (5DL)	S=145.6+(4.909×4DL)	5.848	0.150	176.36±8.13**	175.33±3.87**	0.02

*Values with ** significant at p < 0.01 Differences between measured stature and reconstructed stature*

SEE, Standard error of estimate; R2, Coefficient of determination

inferential statistics, independent sample t-tests, Pearson moment correlation coefficient and Durbin Watson regression step-wise regression equations. Regression line scatter plots were presented using Microsoft Office Excel.

3. Results

The results of the descriptive and inferential statistic of age, stature and five digit lengths of the right hand for males, females and a pooled sample are presented in Table-1. The average ages of 20.48±3.18, 19.75±2.87 and 20.07±3.02 years were recorded for males, females and a combined population. Average stature values were 176.36±8.13, 164.38±6.62 and 169.59±8.79 for male, female and combined samples, respectively. Alongside the mean values and range, the results of an independent sample t-test are represented as statistically significant ($p < 0.01$). This is observed across all the measured parameters, with higher values consistently seen in males. The sexual dimorphism observed indicates that Nigerian males are taller than females, which is reflected by longer digit lengths seen in males than females (Table-1).

Table-2 indicates the Pearson moment correlation coefficients which outline the relationship between stature and the right hand five digit lengths. Looking at the range of 0.40-0.63, it is observed that female values regularly present stronger Pearson correlation coefficient (r) between stature and digit lengths than males, with the weakest value of 0.40 seen in the males' fifth digit length (5DL) and strongest r-value of 0.63 documented for the females' second and third digit length (2DL and 3DL). It can therefore be deduced that female data derived more reliable predictive models.

Table-3 Presents the outcome of comparison between measured and reconstructed stature derived from simple

Table 4- *Comparison between measured and predicted stature derived from simple linear regression models in females using paired t-test.*

Digits Length (cm)	Paired *t*-test in Female Sample					
	Regression Equations	**±SEE**	**R^2**	**Measured Stature (cm) Mean±S.D.**	**Predicted Stature Mean±S.D.**	***p* - value**
First digit Length (1DL)	S=117.3+(7.663×1D)	5.807	0.289	164.38±6.62	164.35±4.62	0.17
Second digit(2DL)	S=107.4+(7.985×2D)	5.142	0.402	164.38±6.62	164.38±4.61	1.14
Third digit Length (3DL)	S=110.8+(6.757×3D)	5.188	0.391	164.38±6.62	164.36±4.73	0.09
Fourth digit Length (4DL)	S=110.3+(7.284×4D)	5.217	0.384	164.38±6.62	164.38±4.01	1.11
Fifth digit Length (5DL)	S=126.1+(6.560×5D)	6.678	0.271	164.38±6.62**	163.29±4.23**	0.04

*Values with **significant at p < 0.01 Differences between measured stature and reconstructed stature*

SEE, Standard error of estimate; R2, Coefficient of determination.

Table 5- *Multiple regression models for stature reconstruction using anthropometric parameters of right and left Direct Digits Length in Male and Female.*

Males	**Multiple Linear Regression Equation**	**±SEE**	**R^2**
Digits Length	SS=(0.72×1DL)+(2.27×2DL)+(3.72×3DL)+(-0.28×4DL)+(0.72×5DL)+115.41	4.241	0.402
Females	**Multiple Linear regression equation**	**±SEE**	**R^2**
Digits Length	SS=(1.67×1DL)+(3.08×2DL)+(0.87×3DL)+(2.38×4DL)+(1.18×5DL)+100.56	4.045	0.506
Pooled Sample	**Multiple Linear regression equation**	**±SEE**	**R^2**
Digits Length	SS=(2.65×1DL)+ (2.56×2DL)+(4.72×3DL)+(1.46×4DL)+ (-0.05×5DL)+83.25	4.006	0.570

linear regression models in the male sample using paired t-test analysis. It is observed that only the least and the weakest correlated parameters 1DL and 5DL recorded a statistically significant difference ($p < 0.01$) between measured and predicted stature in males. Male 1DL presents a statistically significant difference ($p < 0.01$) between measured and predicted stature as 176.36±8.13 and 175.35±4.42, respectively. Fifth DL derived 176.36±8.13 and 175.33±3.87 for measured and predicted stature. However, 2DL, 3DL and 4DL did not show any observable statistical difference. Notably, the higher the standard error of estimate values the lesser the accuracy of prediction; meanwhile, the higher R2 values, the higher the reliability of estimation.

Table -4 Indicates results of comparison between measured and predicted stature derived from simple linear regression models in the female sample using paired t-test. Here, it is noticed that all the parameters predicted stature accurately except 5DL, which records a statistically significant difference ($p < 0.01$) between measured and reconstructed as 164.38±6.62 and 163.29±4.23, respectively. Meanwhile, 1DL, 2DL, 3DL and 4DL all showed stronger correlation as shown in similar values between measured and reconstructed stature. Just like in males, female values also portray proportional R2 values with the respective equations. Meanwhile, an increase in SEE reduces the accuracy of a given variable or the derived equation.

Table-5 depicts results of multiple linear regression equation using Durbin-Watson stepwise method. Three equations are derived from right digit lengths for stature reconstruction in males {SS=(0.72×1DL)+(2.27×2DL)+(3.72×3DL)+(-0.28×4DL)+(0.72×5DL)+115.41}, females {SS=(1.67×1DL)+(3.08×2DL)+(0.87×3DL)+(2.38×4DL)+(1.18×5DL)+100.56} and combined sample size {SS=(2.65×1DL)+ (2.56×2DL)+(4.72×3DL)+(1.46×4DL)+ (-0.05×5DL)+83.25}. It is observed from the equations that the formula derived from the pooled sample showed lower SEE and higher R2 values, respectively, followed by female values and lastly the males. The equations were derived using Durbin-Watson stepwise regression formula as follows: Y=mx+c.

Figures- 3, 4, 5, and 6 represent scatter plots of regression line equations for male and female samples for the five digit lengths and their corresponding coefficient of determination R2.

The scatter line plots derived equations as Y=mx+c, where Y is the estimated stretch stature SS, which is the dependent variable, m is the coefficient of independent variable x and c is the regression line constant or coefficient of regression or the intercept.

4. Discussion

No two populations have the same average mean value for stature (Krishan et al., 2012). The height of a person is one of the foremost attributes used in forensic findings, especially in situations where other sophisticated approaches

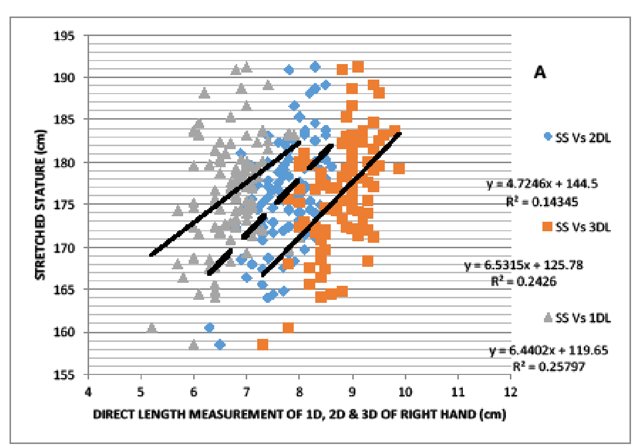

Figure 3- *Scatter plot of stretch stature (cm) vs right hand digits length (cm) of first digit (1DL), second digit (2DL) and third digit (3DL) in the males.*

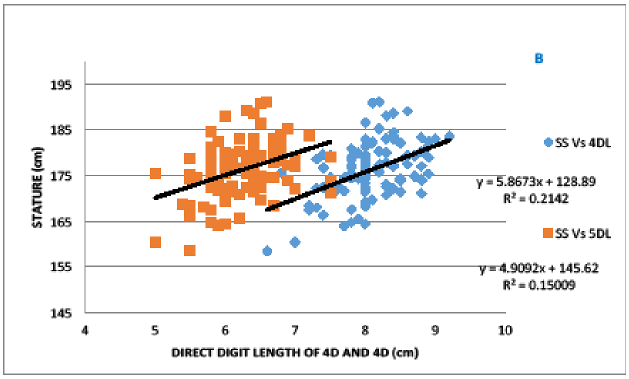

Figure 4- *Scatter plot line of stretch stature (cm) vs right hand digits length (cm) of fourth digit (4DL) and fifth digit (5DL) in the males.*

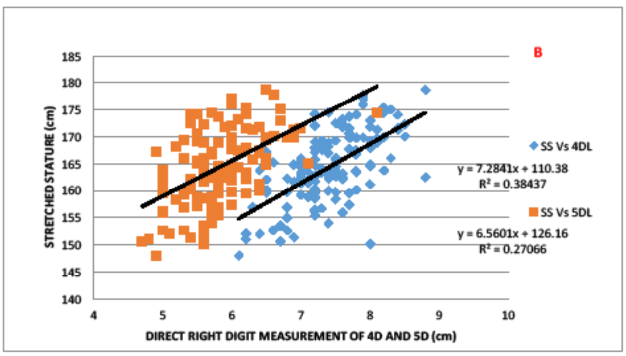

Figure 6- *Scatter plot of stretch stature (cm) vs direct digit length (cm) of fourth digit (4DL) and fifth digit (5DL) in the females.*

are not available to ascertain the identity of people. In such scenarios, amputated digit length of any fingers can be used to reconstruct stature. The use of five digit lengths to reconstruct stature is still unexplored as most studies have dwelled on second to fourth digit ratio and its correlation with stature. Therefore, the present study presents the results of the relationship between five digit lengths and stature.

This study recorded an average stature of 176.36±8.13cm, 164.38±6.62cm and 169.59±8.79cm for males, females and a combined or pooled sample, respectively (Table-1). The mean differences between male and female samples showed a high level of sexual dimorphism at $p < 0.01$ in all the measured parameters, which infers that male adult Nigerians are taller with longer digit

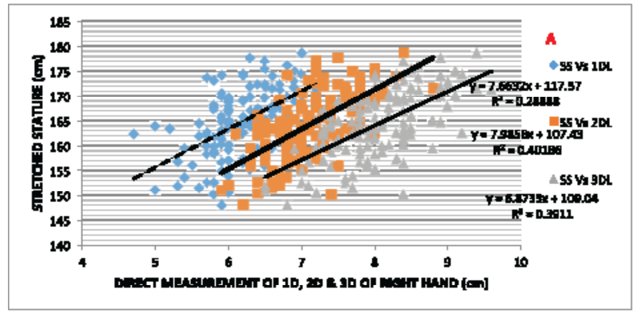

Figure 5- *Scatter plot of stretch stature (cm) vs right hand digit length (cm) of first digit (1DL), second digit (2DL) and third digit (3DL) in the females.*

lengths than females from the same population. This conforms with the results of Matheswaran and Vallabhajosyu [7] on a coastal region of South India, that of Krishan et al. [9] on a north Indian adolescent and Jianpin et al. [17] on the Han population. Even the values of Debbarma et al. [24] from the Regional Institute of Medical Sciences, Imphal, recorded higher mean stature and digit lengths in males than females. Although, all their results had contrasting and contradicting values with that of the recent studies in both genders.

The present results document varying data for Pearson moment correlation coefficient (r), ranging between 0.40 to 0.61 for males' 5DL and 4DL and 0.52 to 0.63 for females' 5DL and 2DL, respectively. Meanwhile, the pooled sample recorded a range of 0.58 to 0.73 for 5DL and 3DL. These results indicate that 5DL showed the lowest and weakest association with stature among all the five-digit lengths, while 2DL, 3DL and 4DL showed the strongest r values with stature. This could be attributed to the fact that regression formulas derived from these variables (2DL 3DL 4DL) recorded more accurate mean predicted stature with less SEE than 1DL and 5DL.

Simple linear regression equations and comparison between measured and predicted stature are presented, respectively for males, females and a combined sample. Statistically, this study has proven that females digit lengths consistently derived more reliable regression equations, as seen from their stronger association with stature than in males, which was further buttressed in the observed lower SEE and higher R2 values. When the results of the regression line equations are compared with reconstructed stature, female samples still showed lower SEE values, which indicates that females' regression formulas are more reliable than that of the males' sample, which is in tandem with the findings of Krishan et al. [9], Debberma et al. [24] and Pal et al., [25] who also reported lower SEE values in females than males and they further concluded that the lower the SEE values, the higher the reliability of a prediction equation.

Several studies have dwelled on estimating stature from second and fourth digit length and their ratio, but the present study was inclusive of all the five-digit lengths (thumb, index, middle, ring and little fingers). Because research involving five hand digit lengths has received little or no attention, this study is of great importance.

The correlation was higher between stature and the right hand five digit lengths in the present study, which is contradictory to the results obtained by Sharma et al. [22].

Bardale et al. [26] also reconstructed stature from index and ring finger length amongst the Sangli and Maharashtra populations. They recorded r-values of 0.52 and 0.62 for males and females right 2DL, respectively, which shows weaker correlation with stature than the current results.

Chandra et al. [23] correlated middle finger length (3DL) with stature and their results showed a positive correlation between 3DL with stature at $p < 0.01$. Their 3DL measurements showed an association of 0.480 with stature and a simple linear equation of $S = 1051.856 + 7.536 \times MFL \pm 63.897$ (mm). Comparing their correlation and predictive formulas for middle finger (3DL) in males and females to that of this study, it is obvious that their equation was not synonymous to the present equation.

The simple linear and multilinear regression models derived from digit Lengths for the five fingers of the right hand in males and females showed different levels of prediction accuracy indicated in the different values of SEE and R2. Differences that exist in SEE values and R2 across variables indicate that different researchers estimate stature with a different level of reliability [22].

The present study showed that the higher the standard error of estimates the lower the accuracy and reliability of prediction; while the lower the error, the higher the precision. This agrees with the work of Krishan et al. [9] and Oria et al. [16]. The finding of Pal et al. [25] also estimated stature from hand dimensions in a Bengali population, West Bengal. Their study confirmed the fact that the higher the R^2 values the higher the likelihood of getting a prediction right, similar to the outcome of this study.

Danborno et al. [8], Oladipo et al. [11], and Jervas et al. [20] have all derived regression equations for stature reconstruction in different Nigerian ethnic groups using second and fourth digits lengths, but there is still paucity of data on five digits lengths in a Nigerian population composed of multi-ethnic groups.

Therefore, the present data and multiple linear regression formulas will act as a reference point for forensic experts trying to assemble the identity of a Nigerian involved in crimes or a victim in disaster.

5. Conclusion

This research presents the standards for stature prediction among adult Nigerians using the lengths of the five digits on the right hand. This will be of use to researchers in this field investigating other age groups in Nigerians. This study has contributed to establishing a database for the Nigerian population. The study has also shown that digit length presents a strong and reliable association for stature reconstruction in both genders.

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Conflicts of interest

There are no conflicts of interest.

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