*Journal of Experimental Research*

*December 2021, Vol 9 No 1*

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# Derivation Of Predictive Equations For Stature Reconstruction From Percutaneous Hand Anthropometry Among Adult Nigerians.

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## ABSTRACT

Determination of sex and living stature are key components of the biological profile for personal identification of individuals. There is limited literature describing such investigation among adult Nigerians. The present study was carried out to develop regression models to estimate living stature and reliably predict sex from percutaneous anthropometric dimensions of the hand in a contemporary adult Nigerian population in Lagos. To derive the regression models, a total of nine (9) anthropometric measurements were recorded for two hundred and twenty-two (222) adult Nigerians (Male 115, Females 107) ranging from 18-65 years of age among them were staff and students of College of Medicine of the University of Lagos and Lagos University Teaching Hospital, Idi-Araba. The direct measurements taken were Hand length, Palm length, Hand breathes, Wrist width and Digit lengths which included thumb, index, middle, ring and little fingers. The result of this present study recorded a significant relationship between gender and stature determination using hand dimensions (p<0.001) as males recorded a mean of 176.49±7.4cm and female recorded a mean of 166.36±7.1cm. Together with stature every other parameter showed statistical significant difference (p<0.01) between male and female. Results for correlation between hand parameters and stature was statistically significant (p<0.01) as different variables showed different degrees and strength of association ranging between 0.411 to 0.625 for left hand and 0.467 to 0.587 for right hand measurements. The weakest correlations were observed in thumb length, little finger and wrist width respectively on the right hand while thumb length and wrist width showed the weakest correlation on the left hand. Regression formulae for reconstructing stature were developed for each of these parameters through simple and multiple linear regressions for stature and logistic regression models were generated for sex estimation with a sectioning point at 0.5. Hand dimensions can be used in Sex and stature determination in medico legal cases if the need arises. This derived equations, thus, provided a new tool for standard in forensic science in medico-legal practice.

**KEYWORDS:** Stature, Equations, Hand, Anthropometry, Regression Models.

## INTRODUCTION

Identification of an individual is the mainstay in forensic investigation. Estimation of stature plays a significant role in establishing personal identity (Zaher et al. 2011). Anthropometric measurements constitute the means of assessing quantitatively the various human variations that exist between individuals, tribes and races (Zeybek et al. 2008). Identification includes determining sex, age, race and stature of a person. Among these, the sex and stature have been reported to be the most important (Zeybek et al. 2008). An individual's stature is described as an inherent characteristic parameter for personal identification (Agnihotri et al. 2009). Various studies have established a relationship between human stature and various body parts dimensions, which allows forensic experts to estimatestature from different parts of the body (Duyar et al. 2006; Rastogi et al. 2008; Agnihotri et al. 2009).

The hand acts as a chief tactile apparatus and is endowed with grasping and precision movements for skilled work (Chaurasia, 1995; Datta, 1995). According to Krishan et al. (2012), age, sex and ethnicity should be considered when estimating stature in forensic examination. Consequently, Krishan et al (2010), Krishan et al. (2012), and Pal et al.

(2016) all reported that genetic and environmental factors such as health, disease, nutrition and physical activity which encourage bone growth and development may affect the stature on individual.

According to Pal et al. (2016), the relationship between different body parts is imperative in the calculation of stature from mutilated and dismembered body parts in forensic examinations. Stature estimation from incomplete skeletal remains or from the mutilated or amputated limbs or parts of limbs or highly decomposed, fragmented human remains highly significant in personal identification in the events of murders, accidents or natural disasters considered as one of the biggest aspects of forensic science.

Anthropometric techniques have been applied by scientists, anthropologists and anatomists for stature and bone length estimation from unknown body parts (Kanchan et al. 2008). This technique has become significant in recent times due to natural disasters like cyclones, tsunamis, earthquakes, floods and man-made disasters like terror attacks, bomb blasts, mass accidents, wars, plane crashes etc. In such cases, the forensic pathologist is often opining about the identity of the deceased (Pal et al. 2016).

The relationship between body segments has been applied in comparing and highlighting the differences between different ethnic groups and to narrate them to locomotor patterns, energy expenditure and lifestyle (Chiba and Terazawa, 1998). This body segment relationship has been the major concern to the anatomists, anthropologists and scientists for many years. Smith (2007), demonstrated that body proportions and the dimensions of different body segments, including the vertebral column, long bones of the limbs and the bones of the hand and foot have been used for stature estimation.

The present study aimed to develop regression models to estimate living stature from percutaneous anthropometric dimensions of the hand in an adult Nigerian population.

## MATERIALS AND METHODS

### Study Design:

To conduct this study ethical clearance was sought and gotten from the Research and Ethics Committee of the College of Medicine of the University of Lagos with clearance No. CMUL/HREC/10/18/452. This cross-sectional study was carried out among students and staff in the college of medicine of the University of Lagos and Lagos University Teaching Hospital, Idi-Araba, in the anthropometry laboratory Department of Anatomy measuring and analyzing the relationship between sex and stature from hand dimensions of two hundred and twenty-two (222) research participant aged 18-65 years selected through random sampling method. This research excluded ethnic believes that do not allow any body contact during measurements, obvious reasons for not understanding the language on the inform consent form, subjects with history of congenital or acquired deformity of the hand were all excluded while it included adult participants whose parents are of Nigeria origin being a student or staff of Nigeria. First, the procedure for measurement, purpose for research and possible benefits were explained to the participants through information contained in the official informed consent document. Participants were recruited at their will and have the right to stop the exercise as he/she so desire. They were assured a confidential and anonymity during and after the exercise.

### Measurement Protocol:

Protocols for direct measurements of stature and hand dimensions were adopted from those established by the International Society for the Advancement of Kinanthropometry ISAK (Ishak et al. 2012a and 2012b). After explaining the study in details to the subject, the procedure of positioning the body, identifying the landmarks and taking measurement were explained to each subject. This was done for the ethical consideration of research protocol. After obtaining consent from the subject, all information was recorded in a structured pro forma. All the measurements were carried out by the same investigator for consistency and accuracy.

The observed measurements were recorded on the recording sheet for all variables. For stretch stature (SS) measurements, it is measured as the vertical distance from the vertex to the floor, where the e vertex is the highest point on the head when the head is held in Frankfurt Horizontal (FH) plane. The subject was made to stand barefoot in an erect posture against the wall with both feet kept close together and hands hanging down on the sides. The distance from the middle of the distal wrist crease to the distal end of most projecting point of hand is the measurement for hand length (HL). Distance between the most lateral points on the head of the 2nd metacarpal to the most medial point on the head of the 5th metacarpal is for hand breadth (Krishan and Sharma 2007). The palm length (PL) measures the distance from the mid-point of the distal transverse crease of the wrist to the proximal flexion crease of the middle finger (Agnihotri et al. 2008). The wrist width (WW) in the distance between the styloid processes of the ulnar and radius bone of the forearm. Digital measurement is the distance between the proximal flexion crease of the finger to the tip of the respective finger, (thumb D1, index D2, middle D3, ring D4 and little fingersD5).All these measurements required manual palpation of the hand to locate the required bony anatomy, the measurements were taken and repeated twice and the mean value recorded.

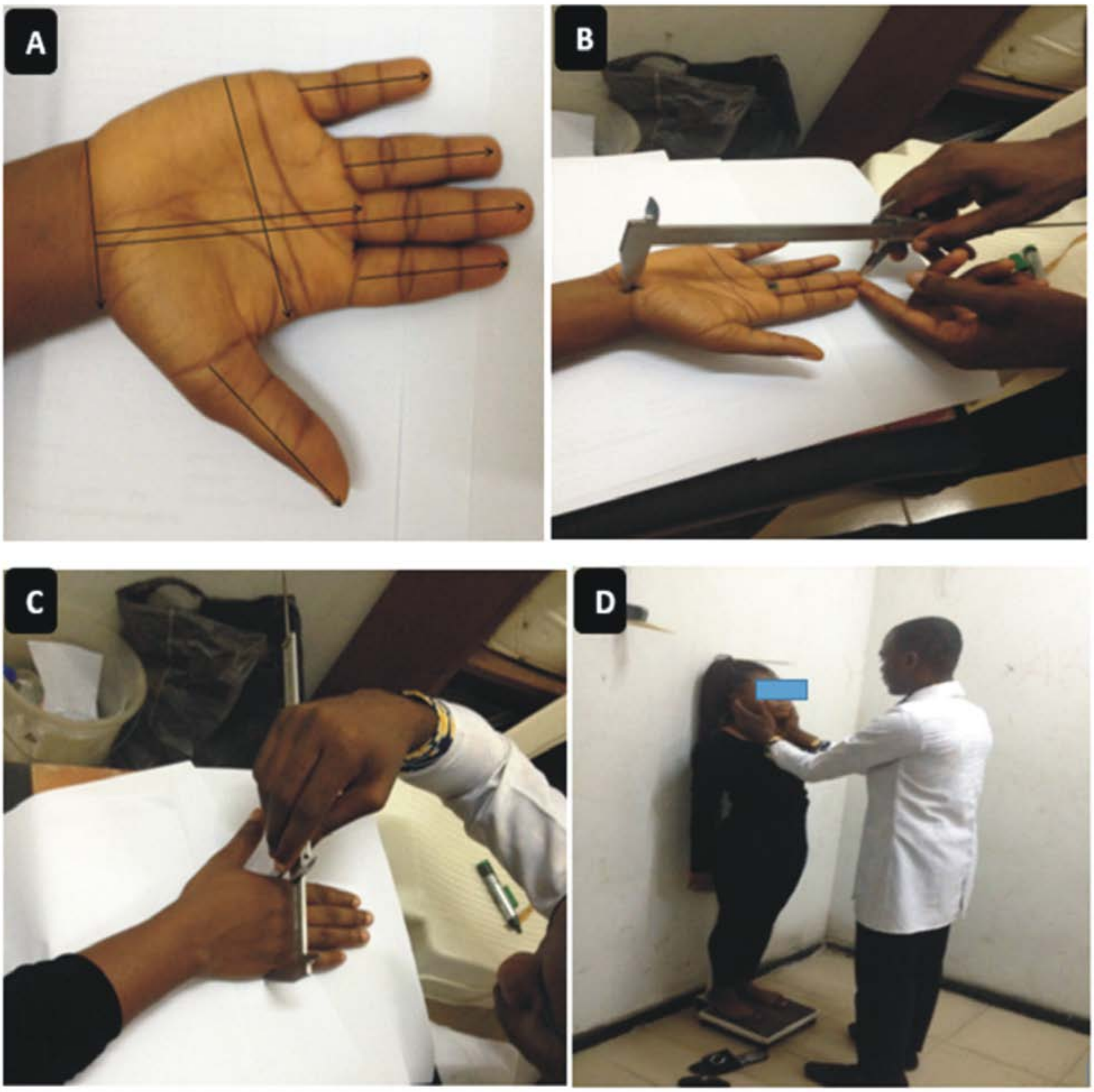



*Figure 1:Showing (A) All measured hand parameters (B) Hand Length measurement (C) Hand breadth measurement (D) Stature measurement*

**Statistical Analysis**

All data was analyzed using Statistical Package for Social Sciences (SPSS) software version 23, Chicago Inc. Descriptive and inferential statistics were presented as mean ± SD, Pearson's correlation coefficients were analyzed to know the relationship between hand dimensions and stature and hand dimension with sex, Simple and Multiple regression models were derived to reconstruct stature while Logistic regression models were derived for sex. Independent t-test was used to ascertain the level of significance between male and female at P-value less than 0.05 ($P<0.05$) and also paired t-test was used to compare right and left hand measurement.

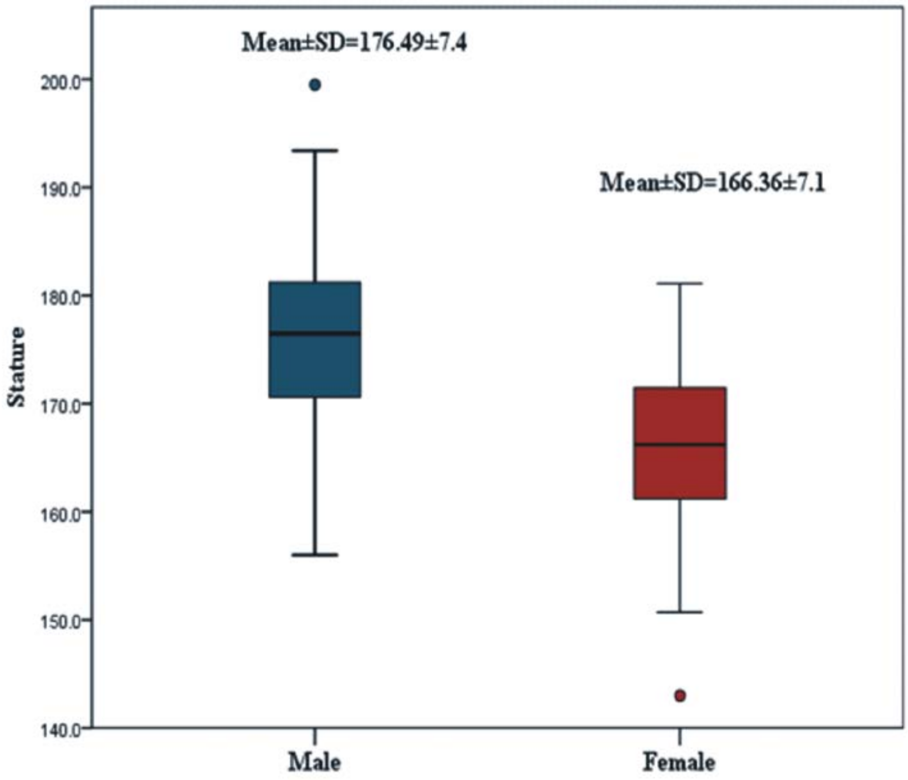
## RESULTS

**Table 1: Descriptive statistics for data used in sex estimation of right hand assessment**

| Right hand | | Mean±SD (CM) | Minimum | Maximum | Standard error |
|---|---|---|---|---|---|
| **Palm length** | Male | 10.89±0.7 | 9.30 | 13.60 | 0.06 |
| | Female | 10.00±0.8 | 8.30 | 12.50 | 0.08 |
| | **Combined** | **10.46±0.9** | **8.30** | **13.60** | **0.06** |
| **Hand length** | Male | 19.23±1.5 | 7.90 | 24.10 | 0.14 |
| | Female | 17.83±1.2 | 12.10 | 20.20 | 0.11 |
| | **Combined** | **18.56±1.6** | **7.90** | **24.10** | **0.11** |
| **Thumb ID length** | Male | 6.43±0.7 | 4.90 | 9.00 | 0.07 |
| | Female | 5.74±0.7 | 4.10 | 7.20 | 0.06 |
| | **Combined** | **6.10±0.8** | **4.10** | **9.00** | **0.05** |
| **Index 2D length** | Male | 7.09±0.7 | 5.20 | 9.20 | 0.06 |
| | Female | 6.54±0.6 | 5.20 | 8.20 | 0.06 |
| | **Combined** | **6.82±0.7** | **5.20** | **9.20** | **0.05** |
| **Middle 3D length** | Male | 8.05±0.7 | 5.70 | 10.40 | 0.06 |
| | Female | 7.47±0.6 | 6.30 | 8.90 | 0.05 |
| | **Combined** | **7.77±0.7** | **5.70** | **10.40** | **0.05** |
| **Ring 4D length** | Male | 7.27±0.6 | 4.90 | 9.60 | 0.06 |
| | Female | 6.72±0.6 | 5.40 | 8.00 | 0.06 |
| | **Combined** | **7.01±0.7** | **4.90** | **9.60** | **0.05** |
| **Little 5D length** | Male | 5.69±0.7 | 3.90 | 8.60 | 0.06 |
| | Female | 5.12±0.5 | 4.20 | 6.60 | 0.05 |
| | **Combined** | **5.41±0.7** | **3.90** | **8.60** | **0.04** |
| **Hand breath** | Male | 8.20±0.5 | 6.10 | 9.60 | 0.05 |
| | Female | 7.20±0.5 | 5.80 | 9.10 | 0.05 |
| | **Combined** | **7.72±0.7** | **5.80** | **9.60** | **0.05** |
| **Wrist width** | Male | 5.46±0.7 | 4.70 | 8.60 | 0.06 |
| | Female | 4.77±0.5 | 4.10 | 7.70 | 0.05 |

**Table 2: Descriptive statistics for data used in sex estimation of left hand assessment**

| Left hand | | Mean ± SD (CM) | Minimum | Maximum | Standard error |
|---|---|---|---|---|---|
| Palm length | Male | 10.84±0.7 | 9.10 | 12.80 | 0.06 |
| | Female | 10.04±0.9 | 8.10 | 12.70 | 0.09 |
| | **Combined** | 10.45±0.9 | 8.10 | 12.80 | 0.06 |
| Hand length | Male | 19.30±1.2 | 15.40 | 24.50 | 0.11 |
| | Female | 17.85±1.2 | 12.30 | 20.30 | 0.12 |
| | **Combined** | 18.60±1.4 | 12.30 | 24.50 | 0.09 |
| Thumb ID length | Male | 6.37±0.7 | 4.80 | 9.10 | 0.07 |
| | Female | 5.75±0.8 | 4.20 | 7.60 | 0.07 |
| | **Combined** | 6.07±0.8 | 4.20 | 9.10 | 0.05 |
| Index 2D length | Male | 7.06±0.6 | 5.20 | 9.30 | 0.06 |
| | Female | 6.46±0.6 | 5.20 | 8.0 | 0.05 |
| | **Combined** | 6.77±0.7 | 5.20 | 9.30 | 0.05 |
| Middle 3D length | Male | 8.04±0.66 | 5.60 | 10.5 | 0.06 |
| | Female | 7.48±0.7 | 5.80 | 9.40 | 0.06 |
| | **Combined** | 7.77±0.7 | 5.60 | 10.50 | 0.7 |
| Ring 4D length | Male | 7.24±0.6 | 4.90 | 9.10 | 0.06 |
| | Female | 6.69±0.6 | 5.10 | 8.30 | 0.06 |
| | **Combined** | 6.98±0.7 | 4.90 | 9.10 | 0.05 |
| Little 5D length | Male | 5.63±0.7 | 3.80 | 8.50 | 0.06 |
| | Female | 5.08±0.5 | 4.10 | 6.80 | 0.05 |
| | **Combined** | 5.37±0.7 | 3.80 | 8.50 | 0.04 |
| Hand breath | Male | 8.13±0.5 | 6.20 | 9.80 | 0.05 |
| | Female | 7.17±0.6 | 5.60 | 9.50 | 0.06 |
| | **Combined** | 7.67±0.7 | 5.60 | 9.80 | 0.05 |
| Wrist width | Male | 5.40±0.7 | 4.40 | 8.50 | 0.07 |
| | Female | 4.74±0.6 | 3.90 | 7.90 | 0.06 |
| | **Combined** | 5.08±0.7 | 3.90 | 8.50 | 0.05 |




**t-value** = 10.356, **p<0.001***

Fig 2: Box Plot showing Sexual differences in measured stature

**Bilateral Asymmetry**

A paired sample t-test table was used to test the mean differences between left and right hand measurements as presented in Table 3. Of all the hand parameters measured, only index 2D length (p<0.001), little 5D length (p<0.003), hand breadth (p<0.001) and wrist width showed a mean significant difference between right and left hand dimensions at (p<0.001).

**Table 3: Paired t-test comparing left and right hand measurements**

| | Difference in Mean (Right-Left) | Standard error (difference) | t-value | p-value | 95%CI |
|---|---|---|---|---|---|
| Palm length | 0.007 | 0.024 | 0.298 | 0.366 | -0.040, 0.055 |
| Hand length | -0.042 | 0.054 | -0.778 | 0.437 | -0.150, 0.065 |
| Thumb ID length | 0.024 | 0.016 | 1.533 | 0.127 | -0.007, 0.055 |
| Index 2D length | 0.050 | 0.015 | 3.469 | **0.001*** | 0.028, 0.079 |
| Middle 3D length | -0.001 | 0.017 | -0.082 | 0.335 | -0.034, 0.031 |
| Ring 4D length | 0.029 | 0.015 | 1.864 | 0.064 | -0.002, 0.031 |
| Little 5D length | 0.046 | 0.015 | 3.015 | **0.003*** | 0.016, 0.076 |
| Hand breath | 0.049 | 0.013 | 3.659 | **0.001*** | 0.023, 0.076 |
| Wrist width | 0.045 | 0.014 | 0.072 | **0.001*** | 0.018, 0.072 |

***Correlation significant at p<0.005**

## STATURE ESTIMATION

### Correlation between Stature and Measured Parameters in Right and Left Dimensions

Table 7 showed a correlation between stature and right and left hand measured parameters. All parameters measured in left and right hand showed a positive significant correlation. The strongest correlations with stature were noted in palm length (r=0.587), and hand length (r=0.568) in the right hand and in the left hand, hand length (r=0.625) and hand breadth (r=0.545) showed the highest correlation.

However, from the table, weakest correlations were shown in thumb length, little finger and wrist width with r=0.467, r=0.467, r=0.469 respectively on the right palm while thumb length (r=0.438) and wrist width (r=0.411) showed the weakest correlation

**Table 7: Correlation between stature and measured parameter in right and left hand**

| | Right | | Left | |
|---|---|---|---|---|
| | Correlation coefficient (r) | p-value | Correlation coefficient (r) | p-value |
| Palm length | 0.587 | <0.001* | 0.547 | <0.001* |
| Hand length | 0.568 | <0.001* | 0.625 | <0.001* |
| Thumb ID length | 0.467 | <0.001* | 0.438 | <0.001* |
| Index 2D length | 0.532 | <0.001* | 0.540 | <0.001* |
| Middle 3D length | 0.554 | <0.001* | 0.519 | <0.001* |
| Ring 4D length | 0.552 | <0.001* | 0.543 | <0.001* |
| Little 5D length | 0.467 | <0.001* | 0.441 | <0.001* |
| Hand breath | 0.554 | <0.001* | 0.549 | <0.001* |
| Wrist width | 0.469 | <0.001* | 0.411 | <0.001* |

***Correlation significant at p<0.001**

In table 8 Correlation between stature and right hand parameters measured showed statistical correlations with the strongest correlations recorded in the hand length (r=0.409) and ring length (r=0.400) in males. Females showed a stronger correlation compared to males in the correlation between right hand parameters and stature. The strongest correlation was seen in the middle length finger and palm length with r = 0.506 and r = 0.448 respectively.

In the left hand, both males and females showed a significant weak correlation between stature and left hand dimensions. The strongest correlation was seen in hand length in males (r=0.453) and in palm length in females (r=0.494). Weakest correlation was also demonstrated in the wrist width of both males and females with r= 0.152 and r=0.291 respectively.

**Table 8: Correlation between stature and measured parameter according to gender in right and left hand**

| | Right | | Left | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| Palm length | 0.341 (<0.001*) | 0.492(<0.001*) | 0.284 (0.002*) | 0.494(<0.001*) |
| Hand length | 0.409 (<0.001*) | 0.453(<0.001*) | 0.453 (<0.001*) | 0.484(<0.001*) |
| Thumb ID length | 0.194 (0.037) | 0.393(<0.001*) | 0.235 (0.011*) | 0.330(0.001*) |
| Index 2D length | 0.385 (<0.001*) | 0.421 (<0.001*) | 0.337 (<0.001*) | 0.455(<0.001*) |
| Middle 3D length | 0.355(<0.001*) | 0.506(<0.001*) | 0.344 (<0.001*) | 0.448(<0.001*) |
| Ring 4D length | 0.400(<0.001*) | 0.437(<0.001*) | 0.374 (<0.001*) | 0.457(<0.001*) |
| Little 5D length | 0.252(0.007) | 0.367 (<0.001*) | 0.231 (0.013*) | 0.325(0.001*) |
| Hand breath | 0.166 (0.076) | 0.385(<0.001*) | 0.218 (0.019) | 0.361(<0.001*) |
| Wrist width | 0.203(0.030*) | 0.345(<0.001*) | 0.152 (0.104) | 0.291(0.002*) |

## STATURE PREDICTIONS FROM INDIVIDUAL MEASUREMENT

Simple linear regression table 9 for individual right hand measurement showed that hand length had the lowest SEEs for all groups (combined ±7.311, male ±6.70, females ±6.40) with the highest coefficient of determination ($R^2$) for the combined 32.3%, females 20.5% and male 16.7%. This was followed by palm length (combined ±7.191, male ±6.99, females ±6.25) and middle 3D length (combined ±7.397, females ±6.194 and males ±6.956).

Table 10. Hand length dimensions from the left hand had the lowest SEEs for all left dimensions measured (combined ±6.93, female ±6.28, and male ±6.63) with the highest coefficient of determination ($R^2$) (combined ±39.1, female ±23.4 and male ±20.5). This was followed by the ring 4D length SEE values of combined ±7.46, female ±6.385 and male ±6.900.

Hand dimensions like wrist width had the highest SEE value (combined ±8.096, female ±6.83, and male ±7.35) with the lowest coefficient of determination (combined 76.9%, females 8.5% and males 2.3%).

**Table 9: Simple linear regression model for stature from Individual measurement in Right hand**

| | Equation | p-value | SEE | R | $R^2$ |
|---|---|---|---|---|---|
| | | **Palm length (Palm length)** | | | |
| Male | 135.76+(3.7) PL | <0.001* | 6.99 | 0.341 | 0.116 |
| Female | 124.24+ (4.2) PL | <0.001* | 6.25 | 0.492 | 0.242 |
| Combined | 109.67+ 5.92 PL | <0.001* | 7.191 | 0.583 | 0.345 |
| | | **Hand length (Hand length)** | | | |
| Male | 138.88+(1.96 )HL | <0.001* | 6.70 | 0.409 | 0.167 |
| Female | 119.66+ (2.62) HL | <0.001* | 6.40 | 0.453 | 0.205 |
| Combined | 112.094+ (3.21)HL | <0.001* | 7.311 | 0.568 | 0.323 |

| | | | | | |
|---|---|---|---|---|---|
| | | **Thumb 1D length (1DL)** | | | |
| Male | 163.317+(2.049) 1DL | <0.001* | 7.30 | 0.194 | 0.038 |
| Female | 141.987+(4.27) 1DL | <0.001* | 6.602 | 0.393 | 0.154 |
| Combined | 138.552+(5.42) 1DL | <0.001* | 7.853 | 0.467 | 0.218 |
| | | **Index 2D length (2DL)** | | | |
| Male | 145.61+ (4.4) 2DL | <0.001* | 0.141 | 0.385 | 0.148 |
| Female | 132.07+(5.2) 2DL | <0.001* | 6.513 | 0.421 | 0.177 |
| Combined | 123.84+(7.0) 2DL | <0.001* | 7.521 | 0.532 | 0.283 |
| | | **Middle 3D length (3DL)** | | | |
| Male | 145.0+ (3.9) 3DL | <0.001* | 6.956 | 0.355 | 0.126 |
| Female | 118.776+(6.3) 3DL | <0.001* | 6.194 | 0.506 | 0.256 |
| Combined | 116.15+(7.14) 3DL | <0.001* | 7.397 | 0.554 | 0.303 |
| | | **Ring 4D length (4DL)** | | | |
| Male | 141.53+(4.80) 4DL | <0.001* | 6.82 | 0.400 | 0.160 |
| Female | 131.01+(6.46) 4DL | <0.001* | 0.183 | 0.437 | 0.191 |
| Combined | 120.22+(7.33) 4DL | <0.001* | 7.406 | 0.552 | 0.305 |
| | | **Little 5D length (5DL)** | | | |
| Male | 160.29+(2.85) 5DL | <0.001* | 7.201 | 0.252 | 0.062 |
| Female | 140.77+(5.0) 5DL | <0.001* | 6.68 | 0.367 | 0.135 |

**SEE- Standard Error of Estimate, p<0.05**

**Table 10: Simple linear regression model for stature from Individual measurement in left hand**

| | Equation | p-value | SEE | R | $R^2$ |
|---|---|---|---|---|---|
| | | **Palm length (PL)** | | | |
| Male | 143.07+ (3.08)PL | 0.002* | 7.135 | 0.284 | 0.081 |
| Female | 127.37+(3.89)PL | <0.001* | 6.241 | 0.494 | 0.244 |
| Combined | 115.01+(5.41)PL | <0.001* | 7.44 | 0.547 | 0.299 |
| | | **Hand length (HL)** | | | |
| Male | 120.87+(2.882)HL | <0.001* | 6.63 | 0.453 | 0.205 |
| Female | 116.46+(2.896)HL | <0.001* | 6.28 | 0.484 | 0.234 |
| Combined | 98.078+(3.95)HL | <0.001* | 6.93 | 0.625 | 0.391 |

| | | | | | |
|---|---|---|---|---|---|
| | | **Thumb 1D length (1DL)** | | | |
| Male | 160.59+(2.50)1DL | 0.011* | 7.23 | 0.235 | 0.055 |
| Female | 140.07+(3.20)1DL | 0.001* | 6.78 | 0.330 | 0.109 |
| Combined | 141.43(4.97) 1DL | 0.001* | 7.98 | 0.438 | 0.192 |
| | | **Index 2D length (2DL)** | | | |
| Male | 149.25+(3.856) 2DL | <0.001* | 7.005 | 0.337 | 0.114 |
| Female | 129.29+(5.737) 2DL | <0.001* | 6.39 | 0.455 | 0.207 |
| Combined | 123.93+(7.04) 3DL | <0.001* | 7.48 | 0.540 | 0.291 |
| | | **Middle 3D length (3DL)** | | | |
| Male | 145.63+(3.84) 3DL | <0.001* | 6.99 | 0.344 | 0.119 |
| Female | 129.26+(5.00) 3DL | <0.001* | 6.42 | 0.448 | 0.200 |
| Combined | 121.21+(6.49) 3DL | <0.001* | 7.59 | 0.519 | 0.270 |
| | | **Ring 4D length (4DL)** | | | |
| Male | 143.25+(4.59) 4DL | <0.001* | 6.900 | 0.374 | 0.140 |
| Female | 131.61+(5.2) 4DL | <0.001* | 6.385 | 0.457 | 0.209 |
| Combined | 121.72+(7.15) 4DL | <0.001* | 7.46 | 0.543 | 0.295 |
| | | **Little 5D length (5DL)** | | | |
| Male | 161.89+(2.59)5DL | <0.001* | 7.24 | 0.231 | 0.053 |
| Female | 144.76+(4.25) 5DL | <0.001* | 6.79 | 0.325 | 0.105 |

**SEE- Standard Error of Estimate, p<0.05**

**Stature Prediction for Multiple Predictors (Digit Lengths)**

Table 11 showed the final models for estimating stature using the 5-digit length measurement in right and left hand in males and females and when combined. The multiple regression table also showed significant results in both left and right hands of males and females and when combined (p<0.001). In addition, the combined gave the highest percentage of coefficient of determination of 32% in both left and right hands while that of males were 15.7% for right hand and 11.1% for left hand. Females had a percentage coefficient of 23.4% in the right hand and 22% on the left hand.

**Table 11: Multiple linear regression model using all 5-digit length measurement**

| | Equation | p-value | Adjusted $r^2$ |
|---|---|---|---|
| | **Right** | | |
| Male | 141.78+ (-2.38)1DL +(3.58)2DL +(0.12) 3DL + (3.93)4DL+ (-0.86)5DL | <0.001* | 0.157 |
| Female | 117.46+ (0.95)1DL+ (-1.61)2DL+(5.59)3DL+ (0.76)4DL+ (1.391)5DL | <0.001* | 0.234 |
| Combined | 114.63+ (0.67)1DL+ (0.463)2DL+(3.05)3DL + (2.847) 4DL+ (1.112) 5DL | <0.001* | 0.319 |
| | **Left** | | |
| Male | 141.19+(-0.53)1DL+(1.185) 2DL+(1.30)3DL + (3.50)4DL+ (-0.979)5DL | 0.003* | 0.111 |
| Female | 120.82+(-0.39)1DL+(2.10) 2DL+(2.24)3DL + (2.41)4DL+ (0.26)5DL | <0.001* | 0.220 |
| Combined | 120.82+(-0.39)1DL+(2.10) 2DL+(2.24)3DL + (2.41)4DL+ (0.26)5DL | <0.001* | 0.315 |

**$^*p<0.05$**

**Stature Prediction for Multiple Predictors (All Measured Parameters)**

Multiple liner regression using all measured dimensions as shown on table 12 also showed significant relationships between stature and gender in both left and right hand.

The most accurate derived regression equation was when combined with an accuracy of 42% in the right hand and 42.8% in the left hand. Females (27.6% right hand; 29.2% left hand) had a greater accuracy compared to males (18% right hand and 17% left hand).

**Table 12: Multiple linear regression model using all measured parameters**

| | Equation | p-value | Adjusted $r^2$ |
|---|---|---|---|
| | **Right** | | |
| Male | 135.32+ (0.61) PL + (1.34)HL (-2.84)1DL +(3.34)2DL +(-1.66) 3DL + (3.71)4DL+(-0.91)5DL+(-1.10)HB +(0.71) WW | <0.001* | 0.180 |
| Female | 101.55+ (1.65) PL + (0.72)HL (0.133)1DL +(-2.75)2DL +(3.39) 3DL + (0.88)4DL+ (0.72)5DL+(0.903)HB +(1.606) WW | <0.001* | 0.276 |
| Combined | 93.03+ (2.141) PL + (1.11)HL (-0.85)1DL +(-0.55)2DL +(1.15) 3DL + (1.66)4DL+ (0.12)5DL+(2.64)HB +(0.64) WW | <0.001* | 0.420 |

| | | | |
|---|---|---|---|
| | **Left** | | |
| Male | 116.76+ (-1.67) PL + (4.09)HL (-0.89)1DL +(0.05)2DL +(-1.41) 3DL + (1.80)4DL+ (-0.62)5DL+(1.32)HB + (0.86) WW | 0.001* | 0.170 |
| Female | 99.99+ (1.81) PL + (1.43)HL (1.65)1DL +(1.67)2DL +(0.78) 3DL + (1.38)4DL+ (0.03)5DL+(0.71)HB +(0.30) WW | <0.001* | 0.292 |
| Combined | 89.27+ (1.22) PL + (2.25)HL (1.19)1DL +(1.16)2DL +(-0.01) 3DL + (1.440)4DL+ (0.47)5DL+(2.767)HB +(-0.34) WW | <0.001* | 0.428 |

**$^*p<0.05$**

## DISCUSSION

The present study explored the use of anthropometric parameters to derive reliable population specific regression equations for stature and sex estimation using hand dimensions. The hand anthropometric parameters are imperative in the reconstruction of the biological profile of the deceased in forensic investigations (Iscan and Quatrehomme, 1999; Krishan, 2007; Kanchan and Krishan, 2011).

Findings from the study included bilateral asymmetry between the left and right hand measurements, correlation between stature and measured parameters using single and multiple predictions and also multiple and linear regression models for estimating stature. The study demonstrated that males have a larger statistically mean difference between stature and left and right hand dimensions as compared to the females. This warranted the need to create sex specific and side specific models. Several comparative studies have reported similar observations with the present study population (Nandi et al. 2018; Ibeabuchi et al. 2018; Ikpa et al. 2019; Ibeabuchi et al. 2020) and other study populations (Ishak et al. 2012; Modibo et al. 2014; Howley et al. 2018).

The current study indicated that the mean of the right hand dimensions was larger than that of the left hand. This was clearly evidenced in the index length, little finger length, hand breadth and wrist width that displayed a significant difference between left and right hand dimensions. This observation clearly demonstrated bilateral asymmetry between the left and right hand dimensions tested. This observation agrees with a study by Howley et al. (2018) that observed a small level of bilateral asymmetry existing between the hand dimensions in an Australian population. In addition, Rastogi et al. (2008), reported the presence of bilateral asymmetry in the left and right hand stating that, right-hand dimensions were larger than the left hand, with statistically significant difference in hand length and hand breadth.

Furthermore, the bilateral asymmetry observed from this study necessitated the need to create side-specific models for estimating stature for each hand dimensions.Findings from this study also demonstrated a statistical significant relationship between stature and gender. Females showed stronger relationship compared to males. This strongest highest correlation was evidenced in the in the right middle length (0.506) against 0.453 in the left hand length of males. This was closely followed by left palm length (0.494) and right hand length (0.492) while in males; other tested dimensions that showed stronger correlations were right hand length (0.409) and right ring length (0.400). Furthermore, the result obtained from the correlation indicated the gender specificity of stature using hand dimensions and the middle length finger showed a significant relationship with stature and can be an important tool for stature estimation as was previously reported by Rastogi **et al. (2008) in an Indian population.** Reasons for this particular observation may be attributed to the fact that *a lot of differences in growth and development between males and females have been reported to affect stature.However, physical growth of females in teens tends to be faster than males and the overall body structure and growth of females are different from boys (*Kanchan and Rastogi, 2009*).*

Similar findings of females having a stronger correlation than males were reported by Rastogi et al. (2008). They reported correlation coefficients ranged from 0.673 to 0.665 and 0.740 to 0.732 in north Indian males and females, respectively. Consequently, in south Indians Rastogi et al. in 2008 reported males to have a higher correlation coefficient of 0.752 to 0.732 compared to females having a correlation coefficient 0.701 to 0.691. In addition, a study by Ibegbu et al. in 2013, reported significant differences between the anthropometric parameters and a significant correlation (≤ 0.001) between the height and hand length, and other parameters in both males and females of Gbagyi school children in a Nigerian population.

This study displayed a positive correlation between stature and hand dimensions tested. In the present study, correlation coefficients for corresponding dimensions ranged between r = 0.411 – 0. 625. Of hand dimensions tested, hand length demonstrated the strongest correlation with stature for all groups (Males and females). Correlations between body dimensions and stature in the present research were similar to those of Ishak et al. (2012), Ibeabuchi et al (2018) and Howley et al. (2018). Ishak et al. (2012) reported correlation coefficients ranging between r = 0.45 – 0.77 for hand dimensions, and hand length demonstrated the highest correlation in most cases. Furthermore, Howley et al. (2018), reported that correlation coefficients for corresponding dimensions ranged between r = 0.43 – 0.95 and of the hand dimensions tested, hand length displayed the strongest correlation with stature for all groups (male, females, combined).

All dimensions were assessed for their ability to predict stature using simple linear regression based upon Standard Error of Estimate (SEEs) and coefficient of determination ($R^2$) values. Of the hand dimensions, the hand length consistently provided the lowest SEEs and highest $R^2$ values as such will be more accurately used in deriving a regression reconstructive model of an individual's hand during identification. However, wrist width in both left and right hand were presented with the highest SEEs. Although they showed significant results, models derived using them will be least applied in reconstruction of the hand and stature estimation using the hand. This finding was consistent with results achieved by Jasuja and Singh (2004), Krishan and Sharma (2007), Agnihotri et al. (2008), Habib and Kamel (2010), Ishak et al. (2012) but contrary to the findings made by Tyagi*et al.* (1999), on subjects from Delhi, India. They reported a positive correlation existed between stature and finger lengths, and it further suggested that the index finger was best for the prediction of stature in both males and females. The SEEs obtained in the present research for hand dimensions from the current study were higher than the comparable models in the previous studies by Jasuja and Singh (2004), Özaslan et al. (2006), Agnihotri et al. (2008), Habib and Kamel (2010), Ishak et al. (2012), Jeong and Jantz 2016), and Howley et al. (2018). The differences in this SEEs level and $R^2$ may be attributed to racial differences and geographical variations that exist amongst individuals of a particular tribe or region.

The index digit in this study indicates to be the best model for reconstructing stature using the 5 digits and hand dimensions tested in both hands is model derived when male and female parameters were combined (combined group). This is because it gave the highest percentage of determination and had the lowest SEE value.

The simple regression models from this study including hand length as well as the combined group in the right and left hand than any of the multiple regression models using 5 digits and all measured parameters achieved lower SEEs. Thus hand length when use as a single variable and model derived from the combined group when use as multiple variable is a good predictor for this sample.

Contrary to this result pattern were studies by Ishak et al. (2012) who reported the single regression equation of left hand length in males performed better than multiple variables, but all other multiple regression models included multiple hand dimensions, with hand length and palm length contributing most to stature estimation and that of Howley et al. in 2018 who noted that the hand length only is a good predictor of stature for the Australians.

Using the models created in this research, stretch stature can be reconstructed in a Nigerian population with a high degree of expected accuracy from isolated body parts including forearm, hand, lower leg and foot. The SEEs achieved for stature estimation models were comparable to and in many instances smaller than other studies. Dimensions of the hand provided the lower SEEs most especially hand length which provided the lowest SEEs. The present study also presented both sex-specific and non sex-specific (or generic) models for the estimation of stature to enable better estimation of stature when sex is unknown or inconclusive.

It is important to note that the regression equations derived in this research to estimate stature from hand dimension is suitable for Nigerians and it would be incorrect to utilize these equations to any other populations in the world. Hence it is recommended that; Further studies should be conducted on various tribes in Nigeria and other ethnicities to generate an all-encompassing data base for stature estimation using hand dimensions.

## CONCLUSION

The present study has contributed to the existing body of knowledge by supplying mathematical models that can be applied in stature reconstruction using the anthropometric hand measurements. Using the models created in this research, living stature can be reconstructed with a high degree of expected accuracy from isolated body parts especially the hand. The SEEs achieved for stature estimation models were comparable to and in many instances smaller than other studies. Dimensions of the hand provided the lower SEEs most especially hand length which provided the lowest SEEs. This research has also presented both sex-specific and non sex-specific (or generic) models for the estimation of stature to enable better estimation of stature when sex is unknown or inconclusive.

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