***Original Research Article***

**Sex-Specific Regression Models for Stature Estimation from Finger Lengths in a Nigerian Cohort**

**ABSTRACT**

**Aim**: Forensic anthropology plays a critical role in the identification of human remains within legal contexts. Among the core parameters in forensic investigations—age, sex, ethnicity, and stature—stature estimation is particularly important when dealing with unidentified, dismembered remains. This study aims to explore the relationship between stature and the lengths of the thumb, index, middle, ring, and little fingers, and to develop both linear and multiple regression models for estimating adult stature based on these measurements.

**Study Design:** Study sample consisted of 284 students (98 males and 186 females) from Olabisi Onabanjo University in South-Western Nigeria, aged between 17 and 27 years.

**Materials and methods**: Each subject was thoroughly examined for stature, finger lengths, hand breadth, and wrist breadth of the right hand. Individuals with vertebral deformities or congenital conditions such as camptodactyly were excluded from the study. The mean ages of the male and female subjects were 21.19 years (SD = 1.41) and 19.79 years (SD = 1.46), All measurements were obtained using standardized techniques.

**Results**: Results indicated that males generally had significantly longer statures and finger lengths compared to females. A positive and statistically significant correlation was found between stature and finger lengths for most fingers, except the little finger in males. Both linear and multiple regression models were created to estimate stature from finger lengths, with the predictive accuracy being higher for females than for males. The study further revealed that the correlation coefficient (R) and coefficient of determination (R²) values were enhanced in the multiple regression models compared to the linear ones.

**Conclusions**: The findings highlight the potential applicability of sex-specific regression models in forensic investigations, emphasizing their utility in stature estimation.

**Keywords**: Anthropometry, Stature, Finger, Linear regression, Correlation, Male, Female

**1. INTRODUCTION**

Over the years, anthropometry has been a crucial tool in studying human variation and plays a significant role in forensic anthropology for the identification of human remains ([Dhulqarnain *et al.* 2020](#_ENREF_11)). The application of anthropometric knowledge extends to the formulation of biological profiles, which are essential for identifying individuals through the estimation of age, gender, and stature of the remains ([Zeybek *et al.* 2008](#_ENREF_37), [Kim 2019](#_ENREF_19)). This process is also vital in determining the cause of death ([Jee and Yun 2015](#_ENREF_17)). In cases involving dismembered bodies, such as those resulting from mass disasters, wars, explosions, or homicides, the identification of individuals often relies on small fragments of the body ([Poorhassan *et al.* 2017](#_ENREF_27)). In such scenarios, accurate identification becomes imperative ([Chandra et al. 2015](#_ENREF_8)).

Various methods have been developed for stature estimation using different body parts, including measurements of upper and lower limb bones such as fingers and phalanges ([Agrawal *et al.* 2013](#_ENREF_1)), hand dimensions ([Ibrahim *et al.* 2016](#_ENREF_15)), upper arm length ([Chandran *et al.* 2016](#_ENREF_9)), ulna ([Torimitsu *et al.* 2014](#_ENREF_35)), femur ([Brits *et al.* 2017](#_ENREF_7)), tibia ([Chibba and Bidmos 2007](#_ENREF_10)), metatarsals ([Bidmos 2008](#_ENREF_6)), and foot dimensions ([Rani *et al.* 2011](#_ENREF_28)). Additionally, some studies have explored the use of soft tissues, bones, and radiological techniques for stature estimation (Meadows and Jantz 1992, Rodriguez et al. 2013).

The estimation of stature from human remains is based on the principle of a linear relationship between the lengths of bones and other body parts and overall stature ([Krishan *et al.* 2012](#_ENREF_20)). Numerous studies have successfully developed accurate models for stature estimation using various body parts. For instance, Ahmed developed a model for estimating sex and stature using upper arm length, ulnar length, and wrist breadth ([Ahmed 2013](#_ENREF_2)). Similarly, Ozden and colleagues estimated individuals' stature by measuring their shoes and foot dimensions ([Ozden *et al.* 2005](#_ENREF_25)). Pelin et al. explored the use of facial and head dimensions for stature estimation ([Pelin *et al.* 2010](#_ENREF_26)). Studies have demonstrated the accuracy of using longer body segments, such as bones of the upper and lower limbs, for stature estimation ([Akhlaghi *et al.* 2012](#_ENREF_3), [Ahmed 2013](#_ENREF_2)). However, there is insufficient studies on the use of finger measurements for stature estimation.

In forensic investigations, particularly in cases of unresolved murders or severe disasters like tsunamis, it is crucial to estimate the stature of victims using various body parts to inform decisions regarding the biological profile of missing or unidentified individuals. This is especially relevant in situations where the bodies of individuals are fragmented or severely damaged, making traditional identification methods challenging. In cases of murder, perpetrators may attempt to conceal the identity of victims by disfiguring their bodies beyond recognition. Therefore, it is essential to establish reliable criteria for creating biological profiles, which can facilitate the identification of individuals who might otherwise remain unidentified.

Human height increases from intrauterine life until about 20-25 years of age, after which it gradually declines, typically by approximately 2.5 cm every 25 years ([Mojaverrostami et al. 2019](#_ENREF_23)). Many studies on various ethnic populations emphasize the importance of stature estimation due to biological variations among individuals from different regions. Consequently, population-specific regression models for predicting stature have been developed. However, limited research has been conducted among the Nigerian population. Therefore, the present study aims to determine the anthropometric relationship between finger length and stature, and to evaluate regression equations for estimating stature among Nigerian students.

**2. MATERIALS AND METHODS**

*2.1. Subjects*

A total of 284 undergraduate students (98 males and 186 females) from Olabisi Onabanjo University, Ogun State, Nigeria, participated in this study. The subjects were aged between 18 and 27 years and were all Nigerian-born. To minimize the impact of diurnal variation in human stature, all measurements were conducted in the morning at the same time. To prevent technical and inter-observer errors, the same researcher performed all measurements using consistent instruments.

In accordance with the ethical guidelines set by the Ethics Committee for Human Experimentation of Olabisi Onabanjo University, each subject was thoroughly examined for stature, finger lengths, hand breadth, and wrist breadth of the right hand. Individuals with vertebral deformities or congenital conditions such as camptodactyly were excluded from the study. The mean ages of the male and female subjects were 21.19 years (SD = 1.41) and 19.79 years (SD = 1.46), respectively. All participants were right-handed to ensure consistency in the measurements. The study received approval from the Research Ethics Committee of the Department of Anatomy, Olabisi Onabanjo University (Approval No. NG.OOU.ANA.REC.2024.46) and was conducted following the principles outlined in the Declaration of Helsinki.

*2.2. Anthropometric Measurements*

Six anthropometric measurements were recorded for each subject as follows:

a) Stature/Height (vertex)

b) Length of the first finger (thumb) on the right hand (LF-1)

c) Length of the second finger (index) on the right hand (LF-2)

d) Length of the third finger (middle) on the right hand (LF-3)

e) Length of the fourth finger (ring) on the right hand (LF-4)

f) Length of the fifth finger (little) on the right hand (LF-5)

The anthropometric measurements of stature and finger lengths were conducted according to the methods described by Vallois ([Vallois 1996](#_ENREF_36)). To maintain consistency, all finger length measurements were taken from the right hand only. The measurements were carried out using a Martin anthropometer and a digital vernier caliper (TTM, Japan) calibrated in centimeters and millimeters.

For stature measurement, subjects stood barefoot on a flat surface with their heads oriented in the Frankfurt plane. Stature was measured as the vertical distance from the vertex point of the head to the floor surface. The subject stood parallel to the anthropometer in an erect posture, gazing forward, while the observer recorded the height indicated on the anthropometer.

Finger lengths were measured on the right hand using a sliding caliper, from the midpoint of the proximal crease of each finger to the tip of the finger. All measurements were recorded in centimeters, as detailed in Table 1.

*2.3. Statistical Analysis*

All statistical analyses were conducted using SPSS software (version 26). To assess gender differences in finger lengths and stature, an Independent Samples t-test was employed. The Pearson correlation coefficient was used to evaluate the relationship between stature and each finger length. Regression analysis was then performed to develop models for estimating stature based on finger lengths. In these models, stature served as the dependent variable, while the lengths of the fingers were treated as independent variables. A p-value of less than 0.05 was considered statistically significant in all analyses.

**3. RESULTS**

*3.1. Descriptive statistics and mean differences*

The mean, standard deviation, and range of age, stature, and finger lengths (FL-1, FL-2, FL-3, FL-4, FL-5) for male and female students are presented in Table 1. The stature of undergraduate students from Olabisi Onabanjo University, Sagamu, Ogun State, ranged from 143.50 cm to 192.00 cm. The mean stature was 174.21 cm for male students and 162.18 cm for female students. The mean measurements of FL-1, FL-2, FL-3, FL-4, and FL-5 for male students were 6.46 cm, 7.14 cm, 8.03 cm, 7.46 cm, and 5.95 cm, respectively. In contrast, the mean measurements for female students were 5.78 cm, 6.45 cm, 7.19 cm, 6.61 cm, and 5.17 cm, respectively.

The results indicate that both mean stature and finger lengths were significantly greater in males than in females (P < 0.001). An Independent Samples t-test was conducted to assess the mean differences in finger lengths between male and female students, and the results are presented in Table 1. All measured parameters were significantly higher in males than in females (P < 0.001). Due to the observed size differences between genders, the correlation coefficients and regression models were computed separately for males and females.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Variables | Gender | | | | | | P |
| Male (N = 98) | | | Female (N =186) | | |  |
| Mean ± SD | Min. | Max. | Mean ± SD | Min. | Max |  |
| Age | 21.19 ± 2.01 | 18.00 | 27.00 | 19.79 ± 1.81 | 18.00 | 28.00 | 0.092 |
| Stature (cm) | 174.21 ± 8.61 | 143.50 | 192.00 | 162.26 ± 6.31 | 145.00 | 190.50 | 0.018\* |
| FL-1(cm) | 6.46 ± 0.97 | 3.36 | 8.94 | 5.78 ± 0.62 | 3.62 | 7.28 | 0.0001\* |
| FL-2 (cm) | 7.20 ± 0.93 | 4.71 | 9.81 | 64.47 ± 0.66 | 4.06 | 8.12 | 0.014\* |
| FL-3 (cm) | 8.03 ± 1.07 | 10.72 | 10.72 | 71.91 ± 0.70 | 4.91 | 9.06 | 0.0001\* |
| FL-4 (cm) | 7.46 ± 1.02 | 4.59 | 10.15 | 66.08 ± 0.70 | 3.82 | 8.24 | 0.0001\* |
| FL-5 (cm) | 5.95 ± 1.01 | 2.96 | 8.90 | 51.71 ± 0.62 | 2.84 | 6.63 | 0.0001\* |

Table 1: Descriptive Statistics and mean difference between male and female age, stature and finger lengths

*3.2 Correlation Analysis*

The relationships between stature and the measured parameters across the entire student population were analyzed using Pearson’s correlation coefficient, and the results are presented in Table 2. Significant positive correlations were found between stature and each of the finger lengths in the overall student population. Among these, FL-4 (r = 0.525, P < 0.001) and FL-3 (r = 0.508, P < 0.001) exhibited the strongest positive correlations with stature.

When analyzing the male students separately, the finger lengths generally showed weak positive correlations with stature, with the exception of FL-4 (r = 0.349, P < 0.001), which showed a moderate correlation. Notably, the correlation between FL-5 and stature in males was not statistically significant (r = 0.190, P > 0.05).

In the female students, FL-2 (r = 0.369, P < 0.001), FL-3 (r = 0.404, P < 0.001), FL-4 (r = 0.365, P < 0.001), and FL-5 (r = 0.346, P < 0.001) demonstrated moderate positive correlations with stature.

*3.3 Linear Regression Analysis*

Linear regression analysis was conducted to estimate stature using the lengths of the first (FL-1), second (FL-2), third (FL-3), fourth (FL-4), and fifth (FL-5) fingers. In these analyses, stature was treated as the dependent variable, while FL-1, FL-2, FL-3, FL-4, and FL-5 were the independent variables. The regression equations derived for estimating stature from finger lengths in the total student population, as well as for each gender separately, are presented in Table 3.

The predictive accuracy for stature estimation was higher in the overall student population, irrespective of gender, compared to the accuracy reported for males and females separately. Among the finger lengths, FL-3 demonstrated the highest coefficient of determination (r² = 0.305) for predicting stature in the total student population (Table 3). For male students, FL-4 (r² = 0.220) provided the highest predictive value for stature estimation, while FL-3 (r² = 0.163) was the most predictive for female students.

Female students exhibited the lowest standard error of estimate (SEE), ranging from ±5.79 to ±6.04, in comparison to male students (±8.11 to ±8.44) and the total student population (±7.81 to ±8.28). A lower SEE value indicates greater reliability in stature estimation.

Table 2: Linear regression equations for estimation of status (in cm) from finger lengths in the whole student population and by gender

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Groups | Regression Equation (cm) | R | R2 | SEE | P |
| Total (N = 284) | S = 137.60 + 4.78 (FL-1) | 0.430 | 0.185 | 8.28 | 0.0001 |
|  | S = 131.03 + 5.27 (FL-2) | 0.485 | 0.235 | 8.02 | 0.0001 |
|  | S = 129.20 + 4.97 (FL-3) | 0.508 | 0.258 | 7.90 | 0.0001 |
|  | S = 10.26 + 5.23 (FL-4) | 0.525 | 0.276 | 7.81 | 0.0001 |
|  | S = 140.00 + 4.85 (FL-5) | 0.453 | 0.205 | 8.18 | 0.0001 |
| Male (N = 98) | S = 161.47 + 1.97 (FL-1) | 0.222 | 0.049 | 8.44 | 0.028 |
|  | S = 157.10 + 2.38 (FL-2) | 0.256 | 0.066 | 8.37 | 0.011 |
|  | S = 155.79 + 2.30 (FL-3) | 0.285 | 0.081 | 8.30 | 0.05 |
|  | S = 152.20 + 2.95 (FL-4) | 0.349 | 0.122 | 8.11 | 0.0001 |
|  | S = 164.54 + 1.63 (FL-5) | 0.190 | 0.036 | 8.50 | 0.061 |
| Female (N = 186) | S = 144.60 + 3.05 (FL-1) | 0.300 | 0.090 | 6.04 | 0.0001 |
|  | S = 139.58 + 3.52 (FL-2) | 0.369 | 0.136 | 5.88 | 0.0001 |
|  | S = 136.16 + 3.63 (FL-3) | 0.404 | 0.163 | 5.79 | 0.0001 |
|  | S = 140.64 + 3.27 (FL-4) | 0.365 | 0.133 | 5.89 | 0.0001 |
|  | S = 143.95 + 3.54 (FL-5) | 0.346 | 0.119 | 5.94 | 0.0001 |

*3.4 Multiple regression analysis*

To enhance the accuracy of stature estimation, multiple regression equations were formulated by combining all measured finger lengths. Table 4 presents the multiple regression equations for estimating stature that incorporate all hand parameters. The regression coefficients for all hand parameters were found to be statistically significant in relation to stature (p < 0.001).

**4. DISCUSSION**

Various studies have demonstrated that individual height can be accurately estimated from the lengths of bones, particularly long bones, which often provide a more reliable prediction of human height. Due to racial differences in phenotypic characteristics and the resulting variations in the ratio of long bone length to height, height estimation often relies on formulas derived from specific bone lengths. The relationship between bone length and height is well-documented in anatomical literature, as well as in forensic, archaeological, and anthropological research ([Feldesman 1992](#_ENREF_13), [Duyar and Pelin 2003](#_ENREF_12), [Chibba and Bidmos 2007](#_ENREF_10), [Mahakkanukrauh *et al.* 2011](#_ENREF_21)). In the present study, we investigated the linear regression formulas necessary for estimating the height of students from Olabisi Onabanjo University in South-Western Nigeria using their finger morphometric values, as well as the relationships between these variables.

Previous studies have consistently shown that stature and hand anthropometric measurements are generally larger in males than in females ([Rastogi *et al.* 2008](#_ENREF_29), [Krishan *et al.* 2012](#_ENREF_20), [Tang *et al.* 2012](#_ENREF_34), [Jee and Yun 2015](#_ENREF_18), [Asadujjaman *et al.* 2019](#_ENREF_4)). For example, Jee and Yun found that in a Korean population, males exhibited greater values in stature, hand length, hand breadth, palm length, and the lengths of the thumb, index finger, middle finger, and ring finger compared to females ([Jee and Yun 2015](#_ENREF_18)). Similarly, studies conducted by Sen et al. in an adult population from North-eastern India ([Sen *et al.* 2014](#_ENREF_32)), and by Krishan et al. in a North Indian adolescent population ([Krishan *et al.* 2012](#_ENREF_20)), reported that ring and index finger lengths were significantly longer in males than in females. Consistent with these findings, our study also demonstrated that males have larger stature and longer mean digit lengths compared to females.

Badyaev explained that sexual size dimorphism in human stature is a result of differences in growth rates during adolescent growth spurts, with males typically growing larger than females ([Badyaev 2002](#_ENREF_5)). The length of the fingers and phalanges has been significantly correlated with stature, reflecting these differences. Krishan et al. reported a correlation coefficient of 0.748 between the index finger and stature in males, and 0.531 in females, within an adolescent population ([Badyaev 2002](#_ENREF_5)). Similarly, Monyeki and Sekhotha found a strong correlation between arm span and stature among South African students aged 15–18 years, with correlation coefficients of 0.76 for both males and females ([Monyeki and Sekhotha 2016](#_ENREF_24)). In another study conducted on 97 young adult women in Iran, the highest correlation between finger lengths and stature was observed with the middle finger, followed by the ring finger, thumb, little finger, and index finger, with correlation coefficients of r = 0.582, r = 0.534, r = 0.455, r = 0.430, and r = 0.398, respectively ([Mojaverrostami *et al.* 2019](#_ENREF_23)). Conversely, Sinan and colleagues reported the strongest correlations between stature and finger lengths in the following order: index finger, ring finger, little finger, and middle finger, with no significant correlation for the thumb ([Jee and Yun 2015](#_ENREF_18), [Sinan and Mahmut 2022](#_ENREF_33)). Jee and Yun demonstrated a positive correlation between finger length and stature in both Korean adults and adolescents ([Jee and Yun 2015](#_ENREF_18)). Consistent with these findings, our study also revealed a positive correlation between finger length and stature. However, in our study, the correlation between finger lengths and stature, from strongest to weakest, followed the order: middle finger, ring finger, index finger, little finger, and thumb. When analyzed by gender, all finger lengths in males were statistically significant predictors of stature, except for the thumb (P > 0.05), which is consistent with the findings of Sinan and colleagues. In contrast, all finger lengths in females showed a positive correlation with stature. Among males, the little finger was the strongest predictor of height, while the thumb was the least predictive. In females, the middle finger was the strongest predictor of height, with the thumb again being the least predictive.

Previous studies have sought to estimate stature using finger lengths in adults from various ethnic groups ([Jasuja and Singh 2004](#_ENREF_16), [Habib and Kamal 2010](#_ENREF_14), [Agrawal *et al.* 2013](#_ENREF_1)). When comparing the regression models derived for stature estimation in this study by gender, it was observed that the models were slightly more accurate in females than in males. This however contradicts the findings of Rhiu and Kim, who reported higher regression values in males ([Rhiu and Kim 2019](#_ENREF_30)).

The regression equations established for estimating stature from finger lengths across different ethnic groups are presented in Table 4. In the present study, the coefficient of determination (R²) for the regression equations using finger lengths was lower than those reported for Indian adults and adolescents, Iranian adults, and Korean adults, for both males and females. Similarly, the coefficient of determination observed in this study is lower than the coefficients of determination observed in Korean adolescents, as reported by Rhiu and Kim (Rhiu & Kim, 2019).

Previous studies conducted on Korean populations have taken into account additional variables known to be highly correlated with stature, such as hand length and palm length ([Jee and Yun 2015](#_ENREF_18), [Rhiu and Kim 2019](#_ENREF_30)). However, in the present study, only finger length was utilized to design the stature estimation model. This approach is particularly relevant in forensic scenarios where obtaining an undamaged hand from a victim at a disaster or murder scene may be challenging. In such cases, estimating stature based solely on finger measurements could be more practical.

For example, Asadujjaman et al. conducted a study on a Bangladeshi population (150 women, aged 18-60 years) and found that the most reliable regression equation for stature estimation was derived from the middle finger, while the index finger provided the least reliable equation ([Asadujjaman *et al.* 2019](#_ENREF_4)). Conversely, Sinan and Mahmut reported that the most reliable regression equation was obtained from the index finger when comparing all five fingers ([Sinan and Mahmut 2022](#_ENREF_33)). In contrast to these studies, our results indicated that the most reliable regression equation for predicting stature in the entire student population was derived from the ring finger (R² = 0.276). Among males, the ring finger (fourth finger) exhibited the highest coefficient of determination (R² = 0.122), while in females, the middle finger (third finger) had the highest coefficient of determination (R² = 0.163).

The coefficient of determination (R²) for stature estimation derived from multiple regression analysis in Korean adults was reported to be 0.425 for males and 0.418 for females ([Rhiu and Kim 2019](#_ENREF_30)). These values are higher than the coefficients of determination observed in the present study. In this study, the coefficients of determination derived from the multiple regression equations were 0.162 for males and 0.169 for females. Sinan and Mahmut found that the multiple regression formula obtained from all five fingers did not yield better results than the linear regression models ([Sinan and Mahmut 2022](#_ENREF_33)), which supports the findings of the present study when analyzed by gender. In fact, the linear regression formulas derived from the entire student population in this study proved to be better predictors of height than the multiple regression formula.

Asadujjaman et al. proposed that regression equations derived from hand length are more reliable predictors of stature than those obtained from finger lengths ([Asadujjaman *et al.* 2019](#_ENREF_4)). In contrast, Sinan and colleague demonstrated that hand width is a better predictor of stature than all finger lengths, except for the index finger ([Sinan and Mahmut 2022](#_ENREF_33)). However, in the Bangladeshi population, the equation for estimating stature from hand width was found to be less reliable than those derived from finger lengths (Asadujjaman et al., 2019). Given that this study focused solely on finger lengths for stature estimation, it is highly recommended that future research should include hand length and other hand measurements to determine which parameters most accurately predict height in specific populations.

**5. CONCLUSION**

This study explored the relationship between finger lengths and stature among undergraduate students at Olabisi Onabanjo University, South-Western Nigeria. Our findings demonstrate that finger lengths can serve as significant predictors of stature, with notable differences observed between males and females. The regression models derived from finger lengths provide a useful tool for estimating stature, particularly in forensic contexts where only partial remains may be available. However, the predictive accuracy of these models was lower compared to studies conducted in other populations, suggesting that the specific characteristics of different ethnic groups should be considered when applying these models. Future research should explore the inclusion of additional hand measurements, such as hand length and width, to enhance the accuracy of stature estimation across diverse populations.

**CONSENT**

As per international standards, written consent has been collected and preserved by the author(s). All the subjects willingly consented to participate actively in the exercise

**ETHICAL APPROVAL**

It is not applicable

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript

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