***Original Research Article***

**Estimation of Stature Using Forearm-Hand Length with Univariate Linear Regression Analysis Among the Igbo Population in Nigeria**

**Abstract**

**Background**: Physical anthropometric analysis for stature estimation is a valid identification process in forensic anthropology and biomedicals. The study aims to estimate stature using the forearm-hand length among the Indigenous people of Igbo, Nigeria.

**Method**: The study adopted a cross-sectional descriptive design to generate physical anthropometric data of standing height and forearm-hand length among the indigenous Igbo. A multi-stage random sampling technique was used, and the sample size was calculated using the Taro Yamane formula. Data were collected directly from the respondent with the aid of a stadiometer and a non-stretchable measuring tape. The data was analyzed using the IBM SPSS version 25.

**Results**: This cross-sectional study examined forearm-hand length and stature anthropometrics among 600 indigenous Igbo individuals (300 males and 300 females) aged 18-35 years. Males showed significantly larger forearm-hand length (FHL) and stature than females, with mean FHL and stature of 50.56±2.86 cm and 176.70±6.46 cm for males, and 47.41±2.25 cm and 165.97±5.02 cm for females. No age-related differences were observed in FHL and stature. FHL was moderately correlated with stature for both sexes (males: R=0.59, females: R=0.54, p=0.0001) and proved to be a good predictor of stature, with the overall model given as S = 80.57 + (1.85 × FHL). Stature prediction was more accurate for males (r²=0.35) than for females (r²=0.42).

**Conclusion**: This study found no age-related differences but significant sex differences in forearm-hand length, which was a better predictor of stature overall, with more accurate predictions for males than females.

**Keywords**: anthropometry, stature estimation, forensic anthropology, biomedicals

**Introduction**

During the development of a human, the processes of differential growth of body parts usually results in changes in its body shape and proportions [1]. A host of linear body parameters are commonly investigated by anthropologists to understand and explain these patterns of allometric growth – some of which include stature (height), and upper limb measurements [2,3]. However, the growth of the upper limbs does not occur independently of changes in overall height. As juvenile humans grow to become adults, both their height and upper limb length increases, although their growth rates usually differ based on genetic, environmental and population-specific factors that they are predisposed to [4-7]. Also, it is important to consider the role of sexual dimorphism in body height (or stature) and limb growth patterns as males tend to have longer limbs relative to their torso in adulthood compared to females [8,9].

The relevance of stature estimation in anthropology has contributed a huge part of the identification process in the field of forensic science. For example, the accurate estimation of stature of a given population can significantly assist in the identification of possible victims from mass disasters, murders, or accidents where bodies are often difficult to recognize [10, 11]. Furthermore, the use of linear regression analysis has enabled researchers globally to establish strong correlations between an individual's stature and various measurements of the upper extremity such as arm length, forearm length, and hand length [12-15]. This present study was aimed at investigating the stature prediction potentials of combined forearm-hand length using linear regression methods. The use of combined length of the forearm and hand in accurately estimating stature is necessary to infer the biological profile of an individual, especially in scenarios where remains of the individual are incomplete or only limb segments are available.

**Material and Methods**

**Study design**

This quantitative research adopted a cross-sectional descriptive research design to generate data on the physical anthropometric parameters (stature and forearm-hand length) among the Igbo ethnic group of Nigeria using the direct anthropometric measure. The study population was indigenous Igbo people residing in an Igbo land of Nigeria which also comprised both sexes (male and female). The study uses Nwewi in Anambra State, Owerri in Imo State, Aba in Abia State, Enugu in Enugu State and Abakiliki in Ebonyi State as the study frames to fully represent the five Igbo States in Nigeria. A multi-stage random proportionate sampling technique was adopted in the study and a quarter of one hundred and twenty Indigenous Igbo was sampled in each state mentioned above. The sample size was calculated using the Taro Yamane formula for descriptive study [16-18]. The study lasted for twelve months (march, 2024 to February 2025).

**Selection criteria**

The study only recruited Indigenous Igbo residing in an Igbo land and had no morphological surgery that could affect stature and forearm-hand length, respondents who also consented and were within the study age interval of 18-35 years were also recruited. The study excludes non-indigenous Igbo, those with morphological defects/surgery that could affect stature and forearm-hand length, those who fail to consent, and those aside from the study age.

**Anthropological landmarks**

The study adopted a direct anthropometric measure on a physical and palpable anthropometric landmark using the non-stretchable measuring tape. The description of the measurements are explained below;

**Stature**

Stature (standing height) is the upright posture of individuals in a standing position and is measured when the individual stood erects with barefoot on the stadiometers with the back of their heads, shoulder blades, buttocks, and heels touching the bar. The measurement is taken from the apex of the head [18].

**Forearm-hand length**

This is a vertical measurement of the forearm-hand where the measuring tape is placed on the prominent lateral humeral condyle to the distal point of the third digit [18].

**Method of data collections**

A semi-structured questionnaire, consent form was issued to every respondent and it was followed with a one-on-one interview. The consent forms were retrieved and the sociodemographic data (age and sex) were recorded on the questionnaire. The anthropometric data (standing height and forearm-hand length) were also collected with the aid of stadiometers and a non-stretchable measuring tape adopting the appropriate anatomical landmarks. All data were recorded and preserved by the authors.

**Method of data analysis**

The data obtained were subjected to statistical analysis using the International Business Machine of Statistical Package for Social Science (IBM SPSS version 25) and results were presented as mean±standard deviation. t-test, Pearson correlation, and regression analysis were used as an inferential statistic, and a probability of less than 0.05 was considered statistically significant at a 95% confidence interval.

**RESULTS**

The cross-sectional study was conducted among the indigenous Igbo within the age of 18-35 years where the majority of the population falls with the age of 21-22 years as described in the Table 1 and the study comprised of 600 hundred indigenous Igbo (300 males and 300 females). Table 1, shows the descriptive statistics of forearm-hand length and stature anthropometry and the finding present that the FHL was 47.41±2.25 cm and stature was 165.97±5.02 cm while the FHL for male was 50.56±2.86 and stature was 17671±6.46 cm. However, the minimum age for male and female was 18years and the maximum age was 40years and the mean value for female was 21.24±2.74 cm, male was 22.74±4.52 cm. for female population

Table 2 shows the sex related differences of forearm-hand length (FHL) and stature (S) anthropometry for Igbo population and the findings present that the female FHL was 47.41±2.25 cm and the male was 50.56±2.86cm while the female stature was 165.97±5.02cm and the male 176.70±6.46 cm. the inferential statistic showed that there is sex difference in forearm-hand length and stature between the Igbo Indigenous males and females.

Table 3 shows the age-related differences in forearm-hand length and stature among the Indigenous Igbo population and the findings present that there was no observable age-related difference (p>0.05) in forearm-hand length and stature among the Igbo ethnic group of Nigeria.

**Stature estimation using forearm-hand length**

Table 4 shows the correlation between the FHL and S among the population, and the findings show that FHL is moderately correlated with stature for both males and females (male: R=0.59, female: R=0.54) and where statistically significant in both male and female populations (p=0.001).

Table 5: shows the summary of the univariate regression analysis for stature estimation using the forearm-hand length among the Igbo population and the findings present that irrespective of the sex, FHL marks a good predictor of stature (r2=0.51) with a minimal standard error of estimate (SEE) of 5.54 and the collinearity test (tolerance: 1.0 and Variance Inflation Factor (VIF): 1.0) has also indicated that FHL could serve as estimative model for stature where the model was deduce as S=80.57+FHL(1.85) (figure 1). while for the male population, S is better predicted using the FHL (r2=0.35) than the female population (r2=4.21) where the female has a lower error margin (SEE=4.21) compared to the male (SEE=5.19) and FHL have been observed to be a better estimative model (tolerance=1.0 and VIF=1.0). however, the estimative model generated for male shows that S=109.27+FHL (1.33) and female was S=108.33+FHL (1.22) (figure 2,3).

**Table 1; Descriptive statistics of anthropometric parameters**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameters | Sex | min | Max | Mean±SD |
| Age (year) | Female | 18 | 35 | 21.24±2.74 |
|  | Male | 18 | 35 | 22.74±4.52 |
| FHL (cm) | Female | 43.1 | 54.2 | 47.41±2.25 |
|  | Male | 44.0 | 57.5 | 50.56±2.86 |
| S (cm) | Female | 156.0 | 179.0 | 165.97±5.02 |
|  | Male | 162.5 | 194.00 | 17671±6.46 |

**Table 2: Sex related differences of FHL and S anthropometric for Igbo population**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | SEX | Mean±SD | SEM | t-test | p-value | Inference |
| FHL (cm) | Female | 47.41±2.25 | .1069 | -18.77 | 0.001 | Significant |
| Male | 50.56±2.86 | .1252 |  |  |  |
| S (cm) | Female | 165.97±5.02 | .23790 | -28.53 | 0.001 | Significant |
| Male | 176.70±6.46 | .28147 |  |  |  |

**Table 3: Age related difference of FHL and S anthropometry for Igbo population**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| AGE | <= 17yrs | 18 – 23yrs | 24 – 29yrs | 30yrs+ | F | p-value | Inference |
| FHL (cm) | 48.54±2.14 | 49.03±3.01 | 49.41±3.13 | 49.50±3.23 | 1.02 | 0.37 | Non- Significant |
| S (cm) | 173.35±5.69 | 171.46±7.83 | 172.54±8.20 | 174.25±8.39 | 2.35 | 0.07 | Non-Significant |

**Table 4: Correlation between FHL and S among Igbo population**

|  |  |  |
| --- | --- | --- |
| **MALE** | | |
| Parameter | R | sig |
| FHL (cm) | 0.59 | 0.00 |
| **FEMALE** | | |
| FHL (cm) | 0.54 | 0.00 |

**Table 5: Univariate regression for stature estimation using forearm-hand length among the Igbo population.**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | B | Std. Error | Beta | R | r2 | SEE | sig | Tolerance | VIF |
| ALL | (Constant) | 80.570 | 2.888 |  | 0.71 | 0.51 | 5.54 | 0.00 |  |  |
| FHL | 1.857 | .059 | .713 |  |  |  | 0.00 | 1.000 | 1.000 |
| MALE | (Constant) | 109.272 | 4.021 |  | 0.59 | 0.35 | 5.19 | 0.00 |  |  |
|  | FHL | 1.333 | .079 | .593 |  |  |  | 0.00 | 1.000 | 1.000 |
| FEMALE | (Constant) | 108.331 | 4.197 |  | 0.54 | 0.29 | 4.21 | 0.00 |  |  |
|  | FHL | 1.216 | .088 | .546 |  |  |  | 0.00 | 1.000 | 1.000 |

Figure 1: scatterplot of stature estimation using the forearm-hand length irrespective of the sex

**Figure 2: scatterplot for stature estimation using forearm-hand length among the male population**

**Figure 3; scatterplot for stature estimation using forearm-hand length among the female population**

**Discussion**

Our study has described the physical anthropometry of the forearm-hand and stature of the Igbo ethnic group of Nigeria and has established a database for males and females between the ages of 18-35 years. The findings from the study described that the mean value for females was 21.24±2.74, for male, it was 22.74±4.52. For the female population, the FHL was 47.41±2.25 and stature was 165.97±5.02, while the FHL for males was 50.56±2.86 and stature was 17671±6.46. These descriptive statistics could be essential in industrial and anthropological classification. In tailoring, they aid size standardization, pattern development, ergonomic design, and efficient mass production, ensuring well-fitted clothing. In anthropology, these measurements support ethnic classification, forensic identification, evolutionary studies, and sports research, helping to analyze population traits, estimates stature from remains, and understand physical adaptations. The average height and forearm-hand could be valuable in fashion design and morphological classification across other ethnicities.

Despite the valuable insight of these anthropometric values of the height and forearm-hand length in industrial, anthropological, and forensic applications, it is warmly felt that this valuable shared a statistical sex difference among the Igbo ethnic group of Nigeria. where it was observed that the males have a higher mean value compared to the females’ populations, and these findings are in consonant with previous studies [12-15, 17-20]. However, Poorhassan et al. [21] revealed in their research that forearm length displayed no sex-related differences among Iranian medical students. These sex-related differences observed among the Igbo ethnic group in our study could be attributed to various factors, such as hormonal influence, growth patterns, or genetic disposition.

In Table 3, our study revealed no related age differences in stature and forearm-hand length among the Igbo ethnic group of Nigeria and these findings could be attributed to the age used in the study because the hard tissue in the forearm arm (radius and ulnar) ossifies before the age of 19years. and this is also applicable to stature. Our work has shown an agreement with a study by Joshi et al. [22] that between 18-23 years.

In forensic application, using the forearm-hand length to estimate and predict stature was highly appreciated in our study and the findings present that irrespective of sex, forearm-hand length could serve as a better predictor of stature (r2 =0.51) where the Variance Inflation Factor (VIF=1) indicating that there is no multicollinearity or relationship with the predictor in the regression model. The estimative model shows a minimal standard error of estimate (SEE=5.54) where the model was deduced as S=80.57+FHL(1.85). These findings agree with a study by Poorhassan et al. [21] that irrespective of sex, r2=0.65 and SEE=6.21. When considering sex-specific data, our study showed that males are better predicted using forearm-hand length (r2=0.35) than females (r2=0.29), though in both sexes, forearm-hand length a better predictor of stature. As indicated (VIF=1, p=0.001). Reasons why males are better predicted using forearm-hand length could be attributed to the fact that their body proportions tend to be more consistent, with a stronger link between forearm length and overall height. In contrast, female body proportions vary more due to factors like hormones, genetics, and earlier skeletal maturity, making forearm length a less reliable predictor. Since males typically experience steadier and longer growth phases, height prediction models based on forearm length work more accurately for them, while female height estimates often require variables.

Conclusively, the estimative model for males is S=109.27+FHL(1.33) and female is S=108.33+FHL(1.22), and these findings are in consonant with previous studies [15, 17-19]. However, our study has shown some similarities and differences with previous studies on the estimation of stature using forearm-hand length, and the differences could be attributed to race, environmental and cultural activities performed in those areas compared to ours.

**Conclusion**

Our study investigated the anthropological analysis of forearm-hand length and stature estimates among the Igbo ethnic group of Nigeria and our findings show no age-related differences while there were observable statistical differences in sex and forearm-hand length was a better predictor of stature irrespective of sex but males were better predicted compared to females using forearm-hand length.

**Consent**

A structured written consent was issued to all indigenous Igbo detailing the rudiments of the study and only those who consented were allowed to participate in the research. afterward, the written consents were retrieved and preserved by the authors

.

**ETHICAL CONSIDERATION**

This study was approved by the research and ethics committee of the university of Delta, Agbor, Delta State, Nigeria.

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 the writing or editing of this manuscript.

References

1. Stulp G, Barrett L. Evolutionary perspectives on human height variation. Biological Reviews. 2016 Feb;91(1):206-34.
2. Bernstein RM. The big and small of it: how body size evolves. American Journal of Physical Anthropology. 2010;143(S51):46-62.
3. Vercellotti G, Piperata BA. The use of biocultural data in interpreting sex differences in body proportions among rural Amazonians. American journal of physical anthropology. 2012 Jan;147(1):113-27.
4. Auerbach BM, Ruff CB. Stature estimation formulae for indigenous North American populations. American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists. 2010 Feb;141(2):190-207.
5. Lettre G. Recent progress in the study of the genetics of height. Human genetics. 2011 May;129:465-72.
6. Cole TJ. The development of growth references and growth charts. Annals of human biology. 2012 Sep 1;39(5):382-94.
7. Gowland R, Walther L. Human growth and stature. The science of Roman history: Biology, climate, and the future of the past. 2018 Apr 3:174-204.
8. Nowak‐Szczepanska N, Koziel S. Sexual dimorphism in growth in the relative length of the forearm and relative knee height during adolescence. American Journal of Physical Anthropology. 2016 Oct;161(2):276-82.
9. Ubelaker DH, DeGaglia CM. Population variation in skeletal sexual dimorphism. Forensic Science International. 2017 Sep 1;278:407-e1.
10. de Boer HH, Blau S, Delabarde T, Hackman L. The role of forensic anthropology in disaster victim identification (DVI): recent developments and future prospects. Forensic sciences research. 2019 Oct 2;4(4):303-15.
11. Klales AR. Current state of sex estimation in forensic anthropology. Forensic Anthropology. 2021 Apr 1;4(2):118-33.
12. Kumar S, Srivastava AK, Sahai MK. Estimation of stature by anthropometric examination of forearm and hand. Journal of Indian Academy of Forensic Medicine. 2010 Mar;32(1):62-5.
13. Ahmed AA. Estimation of stature from the upper limb measurements of Sudanese adults. Forensic science international. 2013 May 10;228(1-3):178-e1.
14. Choudhary S, Singh H, Gupta N. Estimation of stature from combined length of forearm and hand in Jammu region of India. International Journal of Basic and Applied Sciences. 2014 Jan 1;3(1):8-10.
15. Ebrahimi B, Madadi S, Noori L, Navid S, Darvishi M, Alizamir T. The stature estimation from students’ forearm and hand length in Iran. J Contemp Med Sci. 2020 Sep;6:213-7.
16. Fawehinmi HB, Oghenemavwe LE, Okoh PD, Ebieto CE, Irozulike FC, Asiwe N. Stature and Sex Estimation Using Some Linear Anthropometric Parameters: A Cross-Sectional Study of the Igbo Ethnic Group of Nigeria.
17. Oghenemavwe LE, Fawehinmi HB, Okoh PD, Nwofor PN, Asiwe N. Does Upper Arm Length, Arm Span, and Foot Length Serve as Good Predictors for Stature? A Cross-Sectional Study among Northern Nigerians. The foot.;5:10.
18. Asiwe N, Adheke OM, Ezeah I, Okon M, Filima PL, Buseni OV. Discriminant and Multiple Linear Regression Analysis for Sex and Stature Estimation Using Upper Arm and Forearm-Hand Length: A Study among Mgbidi Population of Imo State Nigeria. Asian Journal of Medical Principles and Clinical Practice. 2024 Jun 3;7(1):295-305.
19. Singh B, Kaur M, Kaur J, Singh M, Batra A. Estimation of stature from forearm length in north Indians–an anthropometric study. International Journal of Basic and Applied Medical Sciences. 2013;3(1):201-4.
20. Panjakash S, Londhe S, Mirzanaik AD. Stature estimation from forearm lengths in North Karnataka population; India. Indian Journal of Clinical Anatomy and Physiology. 2019 Jan;6(1):32-7.
21. Poorhassan M, Mokhtari T, Navid S, Rezaei M, Sheikhazadi A, Mojaverrostami S, Hassanzadeh G. Stature estimation from forearm length: an anthropological study in Iranian medical students. Journal of Contemporary Medical Sciences. 2017 Jun 1;3(11):270-.
22. Joshi A, Thorat SS. Gender Differences in the Relationship between Forearm Length and Height across Different Age Groups: A Correlation and Regression Analysis. Advances in Human Biology. 2024:10-4103.