**Original Research Article**

**Discriminant and Multivariate Regression Analysis for Estimating Sex and Stature Using Upper Limb Anthropometric Measurements Among the Yoruba Ethnic Group of Nigeria**

**Abstract**

**Background:** Estimating sex and stature using body measurements is an important aspect of forensic anthropology, bioarchaeology, and human identification.

**Aim:** The study aimed to articulate the stature model using arm length, forearm-hand length and arm span amongst the Yoruba ethnic group of Nigeria.

**Method:** Standardized anthropometric techniques were used to measure the data. The Statistical Package for the Social Sciences (SPSS), version 23, was used for data analysis. Discriminant and multivariate regression were used to estimate sex and stature. A probability less than 0.05 (p<0.05) was considered statistically significant, and 95% was denoted as the confidence level. **A** total of 400 subjects (200 females and 200 males) between the ages of 18-40 years were recruited for the study.

**Result:** The multivariate regression among the sexes to estimate stature using arm length, forearm-hand length, and arm span shows (R=0.82, SEE= 4.74), the stature predictive power of male was (R= 0.65, SEM=4.25) and the female stature (R= 0.75, SEM=4.14). The estimation for sex shows overall significance (X2=252.28, ƛ= 0.53, p<0.05).

**Conclusion:** The study shows a stronger correlation in all subjects. Also, it indicates that there is a stronger correlation in females than in males. Therefore, arm length, forearm-hand length and arm span can be used to predict height.

**Keywords:** Discriminant; Multivariate; Yoruba; Anthropometric

**Introduction**

Estimating sex and stature using body measurements plays an important role in forensic anthropology, bioarchaeology, and human identification [1]. Moreover, these measurements are particularly useful in forensic investigations, disaster victim identification, and anthropological research, where complete skeletal remains or full-body measurements may not be available [2,3].

However, several studies have been researched on stature estimation in various upper and lower extremities. Oghenemavwe et al., [4] conducted research among the Igbo ethnic group of Nigeria on the multivariate regression model for stature estimation from arm span, horizontal fingertip reach, and foot length, which shows that there was no sexual dimorphism among the parameters. Dongre et al. [5] researched the young adults of the Western Indian population on the correlation of the stature to forearm length, which indicated that the left forearm was more accurate in estimating stature. Fawehinmi et al., [6] conducted a study on the Hausa ethnic group of Nigeria on stature estimation using arm span, arm length, and forearm-hand length, where arm span and foot length show a positive correlation between stature in both sexes. Another study revealed that foot, forearm and hand lengths are correlated with height among the Iranian and Pakistani medical students Jouzdani et al., [7].

To predict the sex and stature of an individual based on specific body anthropometric measurements, there is a need for the implication of discriminant function analysis, which helps to utilize body morphological difference based on the prediction of the sex and stature. However, these functions essentially act as decision rules that assign a probability of sex and stature classification to an unknown individual based on their skeletal measurements. Given the significance of population-specific data in forensic and anthropological studies, this research focuses on the Yoruba ethnic group, providing valuable insights into the applicability of these methods for identification and anthropometric assessments. The findings contribute to forensic science, physical anthropology, and medical studies by offering reference standards that can assist in cases requiring biological profiling and identification.

**2.0 MATERIALS AND METHODS**

**2.1 Study Design**

 A total number of four hundred subjects (200 males and 200 females) between the ages of 18-35 years made up the population. A cross-sectional descriptive research method was adopted. The study was at Lead City University in Ibadan State, where the subjects were selected using a multi-stage random proportionate sampling approach.

**2.2 Selection Criteria**

**Inclusion Criteria**

 Aged between 18 and 37 years with no history of body surgery were selected. Additionally, those whose parents and grandparents belonged to the Yoruba ethnic group of Nigeria.

**Exclusion Criteria**

Those who had damage or abnormalities in hand morphology or stature, and subjects who did not meet all of these inclusion criteria were excluded from the study.

**2.2.1 Anthropometric landmarks**

The study used some anthropometric variable measures (stature, arm length, forearm-hand length and arm span), and these variables are defined as follows;

**2.2.2. Stature**

To use the Goodcare ZT-160 stadiometer, subjects stood upright and barefoot on the level platform, touching the bar with their backs of their heads, heels, buttocks, and shoulder blades. They were instructed to relax and keep their arms at their sides, and pains were taken to prevent them from sagging.

**2.2.3. Arm Span**

With both arms extended laterally at 900 shoulder height, perpendicular to the body and parallel to the floor, the subject’s upright posture is measured by the distance between the tips of their middle fingers.

**2.2.4. Arm length**

This is measured from the lateral tip acromion down to the distal part of the arm (lateral and medial epicondyle).

**2.2.5. Forearm-hand length**

This is measured from the radius's proximal head to the third finger's most distal limit.

**2.3. Method of Data Collection**

To ensure that the subjects met the inclusion criteria and were fit to participate in the study, sociodemographic data for the Yoruba indigenous people in Nigeria were collected through a semi-constructive descriptive questionnaire and a personal interview. The authors recorded and preserved the data readings. The arm length forearm-hand lengths and arm span were measured using a mega-size calliper, adopting the appropriate anatomical landmarks.

**2.4 Method of Data Analysis**

Data obtained were subjected to statistical analysis using the International Business Machine of Statistical Package for Social Science (IBM version 25). Results obtained were presented in the table as mean ± standard deviation. T-test was used as an inferential statistic to evaluate sexual. Discriminant and linear regression were used to estimate sex and stature. A 95% confidence level was used, and a probability of less than 0.05 (p<0.05) was deemed statistically significant.

 **3.0 Result**

The descriptive assessment between the Yoruba subjects showed in Table 1, that the mean value of stature of 170.51±8.29cm, arm length of 32.21±3.78cm, forearm-hand length of 46.64±4.75cm, and arm span of 176.40±11.62cm, respectively. The inference has shown there were sexual differences among the parameters (Table 2). Table 3, shows the multivariate regression analysis for all Yoruba subjects on stature estimation using stature, arm length, forearm-hand length, which were statistically significant across the parameters from the Collinearity Statistics Variance Inflation Factor (VIF), which have shown that the parameters have strong correlation for stature (VIF<2). The standard error of estimation has shown the accuracy of the prediction (SEE< 1). Table 4, displays multivariate regression analysis for males which shows that it has a strong significant value (p<0.05) to stature estimation in males and its accuracy of the prediction across the parameters was observed to be high (SEE<1) and it equally shows that the collinearity of the parameters further indicated that the parameters are good predictors of stature (VIF<2). Table 5, among the females, our results present a strong correlation showing that the overall prediction was significant (p<0.05) with a high level of accuracy (SEE<1) of the parameters to stature estimation. However, the collinearity of the parameters to stature estimation has shown that the parameters are good predictors for stature (VIF<2). Table 6, a summary of multivariate regression of stature estimation among all subjects, shows the correlation coefficient (R=0.82, SEE= 4.74) with a standard error of estimate. A comparison between the males and the females has shown that the females have a better prediction of stature (R= 0.75, SEM=4.14) than the male’s stature (R= 0.65, SEM=4.26). Table 7, shows the discriminant analysis using the stature to classify sex with arm length, forearm-hand length and arm span. The overall chi-square test shows a significant value (X2=252.28, ƛ= 0.53), canonical correlation = 0.69, df= 4, and p<0.05). The sexual centroid displayed that the male was 0.95 while the female was 0.95. The Canonical Discriminant Coefficient shows (S)0.96+(AL)-0.19+(FAL)0.48+(AS)0.25 across the sex, while for specificity and validity, the discriminant classification coefficient model is; *Male=-342.30+(S)4.05+(AL)-0.16+(FAL)0.19+(AS) 0.65 while Female=-389.15+(S)4.23+(AL)0.25+(FAL)0.43+(AS)0.12*

**4.0 DISCUSSION**

The present study estimates the sexual dimorphism using arm length, forearm-hand and arm span among Yoruba ethnic group of Nigeria. The finding presents the mean of males was stature of 175.89±6.41cm, arm length of 33.49±3.69cm, forearm-hand length of 49.23±3.64, and arm span of 183.28±9.45 while females had 165.14±6.23cm, 30.94±3.43cm, 44.04±4.29cm, 169.53±9.30cm for stature, arm length, forearm-hand length and arm span respectively. However, the findings of this study have shown that males have a higher mean value compared to females, which is consistent with the biological and genetic factors that play a major role in the average height difference between males and females. Also, during puberty, testosterone plays a significant role in stimulating bone growth, particularly in the long bones of the arms and legs, leading to increased height [8, 9]. In contrast, females experience a surge in estrogen, which promotes bone maturation and causes the growth plates to close earlier than males, limiting their final height [10, 11]. Additionally, evolutionary and biological factors contribute to this difference, as greater height and strength in males may have been advantageous for survival and reproduction in early human societies. While environmental factors such as nutrition and overall health can influence height, the biological and hormonal differences between males and females remain the primary reasons for the height disparity [12, 13]. The sexual variance shown in this study is in line with other research across many populations, which found that males and females differ significantly (p<0.05) Fawehinmi et al., [14], Fawehinmi et al., [15]; Oghenemavwe et al., [16], and Mulu and Sisay, [17].

However, the present study exhibited a strong correlation coefficient of sex between stature, arm length, forearm-hand length and arm span (R= 0.82, SEE= 4.74), and this would be reliable for predicting human stature. However, when comparing the sex using anthropometric parameters, the finding shows that females (R= 0.75, SEE= 4.14) have a prediction using arm length, forearm-hand length and arm span than males (R= 0.65, SEE= 4.25), this could be attributed to environmental, cultural and biological factors. The findings of this study agree with the findings of Oghenemavwe et al., [18], Pajokh et al., [19], and Howley [20]. Our study showed the stature model for males, S=93.35+(AL)0.18+(FHL)0.19+(AS)0.37 and females, S=74.59+(AL)0.16+(FHL)0.19+(AS)0.46.

Sexual discrimination was also explored to classify sex (male and female) arm length, forearm-hand length and arm span. The findings of this study present that the stature estimation using arm length, forearm-hand length, and arm span was significant (X2=252.28, ƛ= 0.53, p<0.05). Where the sex centroid shows that applying the discriminant model 𝑆𝑒𝑥=(S)0.96+(AL)-0.19+(FHL)0.48+(AS)0.25, with the study parameters, a positive resultant value from 0-0.95 predicts males and from 0 - 0.95 predicts females. The findings have shown that group membership of the males was 86% and females was 84%, which were correctly predicted, which account for 85% of the total sexes were correctly classified. Our findings agree with the work of Fawehinmi et al., [21], Fawehinmi et al., [22]; Karadayı et al., [23] and Dey and Kapoor [24], showing that the sex estimation accuracy varied from 83% to 87%.

The study has shown some similarities and differences in sex and stature estimation using arm length, forearm-hand length and arm span among various populations, and these differences could be attributed to various factors, like race factors, body composition and environmental factors.

**Table 1. Descriptive Statistics of Yoruba Subjects**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | N | Minimum | Maximum | Mean | Std. Deviation |
| stature | 400 | 150.00 | 193.00 | 170.5160 | 8.29653 |
| arm length | 400 | 20.00 | 42.00 | 32.2158 | 3.77756 |
| Forearm-hand length | 400 | 31.50 | 56.00 | 46.6352 | 4.74716 |
| arm span | 400 | 103.00 | 200.00 | 176.4013 | 11.62143 |

**Table 2. Sexual Differences of the Yoruba Subjects**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameters  | Male  | Female  | T-test  | P-value | Inference |
| S (cm) | 175.89±6.41 | 165.14±6.23 | 17.012 | 0.00 | S  |
| AL (cm) | 33.49±3.69 | 30.94±3.43  | 7.174 | 0.00 | S |
| FHL (cm) | 49.23±3.64 | 44.04±4.29 | 13.020 | 0.00 | S |
| AS (cm) | 183.28±9.45 | 169.53±9.30 | 14.667 | 0.00 | S |

*S=Stature, AL= Arm length, FHL= Forearm-hand length, AS= Arm Span, S= Significant*

**Table 3. Multivariate Regression Analysis in all Subjects Where Arm Length, Forearm Length and Arm Span Estimate Stature**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model  | Unstandardized Coefficients | StandardizedCoefficient | t | Sig.  | Collinearity Statistics  |
|  | B | Std. Error | Beta |  |  |  Tolerance  | VIF |
| (S) (constant)  | 66.818 | 3.653 |  | 18.293 | .000\* |  |  |
| AL (cm) | .118 | .083 | .054 | 1.409 | .160# | .567 | 1.765 |
| FHL (cm) | .336 | .073 | .192 | 4.595 | .000\* | .467 | 2.140 |
| AS (cm) | .478 | .025 | .669 | 19.236 | .000\* | .676 | 1.480 |

*S=Stature, AL= Arm length, FHL= Forearm-hand length, AS= Arm Span, \*= Significant, #=Not Significant*

**Table 4. Multivariate Regression of Stature Estimation in Yoruba Male Subjects**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model  | Unstandardized Coefficients | StandardizedCoefficient | t | Sig.  | Collinearity Statistics  |
|  | B | Std. Error | Beta |  |  |  Tolerance  | VIF |
| (constant) | 93.352 | 6.910 |  | 13.509 | .000\* |  |  |
| AL (cm) | .175 | .119 | .101 | 1.474 | .142# | .628 | 1.592 |
| FHL (cm) | .199 | .129 | .113 | 1.539 | .126# | .544 | 1.839 |
| AS (cm) | .365 | .043 | .538 | 8.566 | .000\* | .743 | 1.346 |

*S=Stature, AL= Arm length, FHL= Forearm-hand length, AS= Arm Span, \*= Significant, #=Not Significant*

**Table 5. Multivariate Regression of Stature Estimation in Yoruba Female Subjects**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Model  | Unstandardized Coefficients | StandardizedCoefficient | t | Sig.  | Collinearity Statistics  |
|  | B | Std. Error | Beta |  |  |  Tolerance  | VIF |
| (S) (constant) | 74.585 | 5.708 |  | 13.068 | .000\* |  |  |
| AL (cm) | .155 | .107 | .085 | 1.454 | .148# | .644 | 1.553 |
| FHL (cm) | .192 | .085 | .132 | 2.248 | .026# | .639 | 1.566 |
| AS (cm) | .456 | .032 | .681 | 8.566 | .000\* | .943 | 1.060 |

*S=Stature, AL= Arm length, FHL= Forearm-hand length, AS= Arm Span, \*= Significant, #=Not Significant*

**Table 6. Summary of Multivariate Regression Model of Stature Estimation of Yoruba Subjects using Arm Length, Forearm-hand Length and Arm Span**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Subjects  | Multivariate model  | R  | R Square  | Std. Error of the Estimate | Sig. F Change |
| All  | S=66.82+(AL)0.12+(FHL)0.34+(AS)0.48 | 0.82 | 0.676 | 4.738 | 0.00\* |
| Male | S=93.35+(AL)0.18+(FHL)0.19+(AS)0.37 | 0.65 | 0.426 | 4.893 | 0.00\* |
| female | S=74.59+(AL)0.16+(FHL)0.19+(AS)0.46 | 0.65 | 0.575 | 4.142 | 0.00\* |

*S=Stature, AL= Arm length, FHL= Forearm-hand length, AS= Arm Span, \*= Significant*

**Table 7. Sex Discriminant Function of Yoruba Subjects using Arm Length, Forearm Length and Arm Span**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Eigenvalue | Canonical Correlation | Wilks’ Lambda | Chi-Square | df | Sig. |
| 0.89 | 0.69 | 0.53 | 252.28 | 4 | 0.000\* |
| Sex centroidMale = 0.95Female = -0.95 | Canonical Discriminant Coefficient  |  |
| (S)0.96+(AL)-0.19+(FHL)0.48+(AS)0.25 |
| Classification Coefficient  |  | Predicted Group Membership |  |
| Male=-342.30+(S)4.05+(AL)-0.16+(FHL)0.19+(AS) 0.65  |  | Male  | Female  |
| Female=-389.15+(S)4.23+(AL)0.25+(FHL)0.43+(AS)0.12 | Male  | 172 | 28 |
|  | Female  | 32 | 168 |
|  |  | 86% | 14% |
|  |  | 16% | 84% |

*S=Stature, AL= Arm length, FHL= Forearm-hand length, AS= Arm Span, \*= Significant, 85% of original group cases correctly classified*

**5. CONCLUSION**

In conclusion, comparing the mean anthropometric values of the Yoruba ethnic group shows that males have higher anthropometric measurements than females. The study equally shows a stronger correlation in all subjects. It also indicates that there is a stronger correlation in females than in males.

**CONSENT AND ETHICAL APPROVAL**

Ethical approval was obtained from the Research Ethics Committee of the University of Port Harcourt, Port Harcourt, Nigeria (UPHCEREMAD/REC/MM/91/046). All subjects were adequately informed about the study procedure. They gave their consent in writing.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declares 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.

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