Evaluation of sexual dimorphism by discriminant function analysis of toe length (1T–5T) of adult Igbo populace in Nigeria

Stephen A. Alabi1,2, Blessing C. Didia2, Gabriel Sunday Oladipo2, Eric O. Aigbogun Jr.2

INTRODUCTION

The application of somatometry (a significant aspect of anthropometry) in the identification of human remains led to the formation of term “forensic anthropometry.” The ultimate aim of using anthropometry in forensic medicine/science is to assist the law enforcement agencies achieve “personal identity” in cases of unknown human remains;1 which involves the combination of different procedures. However, those set of physical characteristics, functional or psychic, normal or pathological that defines an individual can be regarded as identity.2

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Alabi SA, Didia BC, Oladipo GS, Aigbogun EO. Evaluation of sexual dimorphism by discriminant function analysis of toe length (1T–5T) of adult Igbo populace in Nigeria. Niger Med J 2016;57:226-32.
Various studies have established sexual differences from different human bones such as the skull, pelvis, clavicle, and smaller bones such as metatarsals, metacarpals, phalanges, patella, vertebrae, ribs, and other vital structures such as dentition. The most widely applied statistical model in sex determination is the discriminant function analysis (DFA) established by Fisher. This model encouraged many forensic scientists to assess their anthropometric data accordingly and critically.

MATERIALS AND METHODS

A total of 420 subjects within the age range; 18–65 years, equally distributed into males and females of Igbo descent, traced to paternal and maternal grandparents were selected. The Igbo population was estimated from the percentage contribution of the various ethnic groups to the Nigerian population, while the sample size was determined by proportion using Fisher’s formula for large population (>10,000) or infinite population; \[ SS = \frac{Z^2 \times p \times q \times n}{d^2} \]

Subjects were selected by multistage stratified sampling technique. Structured questionnaires were used to determine sociodemographical status of the subjects and written informed consent was obtained from each participant. All subjects were healthy individuals free of deformity, injury, fracture, amputation or any surgical procedures carried out on the toes. Ethical clearance was obtained from the University of Port Harcourt Ethical Committee prior to the commencement of the study.

Anthropometric determination of toe length was carried out using a digital Vernier caliper with precision of 0.01 mm. The following toe measurements were taken; 1T-great toe (hallux), 2T-long toe (second toe), 3T-middle toe (third toe), 4T-ring toe (fourth toe), and 5T-little toe (fifth toe) for both foot. The toe length was defined by the distance from the tip of the toe till the proximal metatarsophalangeal crease of that toe; when fully extended [Figure 1]. Measurements were taken trice and the average tabulated as the value for the measured length.

Statistical analysis

Statistical Package for Social Sciences (IBM, version 23, Armonk, New York, USA) ANOVA and unpaired t-test was used in assessing the sex differences in the measured parameters, and univariate DFA was used to ascertain the possibility of classifying the parameters into group membership. Only statistically significant or close to significant variables were selected for DFA. The confidence level was set at 95%; hence, \( P \leq 0.05 \) was considered to be statistically significant.

DATA ANALYSIS

The results were presented based on the anthropometric measurements of toes length (1T–5T) for both feet. Continuous data were represented as mean (standard deviation [SD]), whereas frequency (%) for other categorical data. The sociodemographic characteristics of the subjects were represented in Table 1. The values observed from the anthropometric measurements were tabulated and the mean (SD) values, and range (minimum – maximum) were determined for the sex (male and female) [Table 2] with side specific differences (left and right) evaluated. The Levene’s ANOVA; prompting specific t-test was used to compare the mean difference (MD) in the values obtained for sex with 95% confidence interval for observed MDs [Tables 3 and 4]. The DFA was presented in tables using foot parameters. The models are described in Tables 5-10 with it summary membership classification in Table 11.

RESULTS

The study comprised 420 subjects, of equal proportion of males (50%) with mean (SD) age of 25.26 ± 6.06 years and females (50%) with mean age of females 24.55 ± 5.79. A larger proportion of males (197; 51.4%) and females

| Variables         | Sex (n) | Total   |
|-------------------|---------|---------|
| Age (years)*      | 25.26±6.06 | 24.55±5.79 | 24.91±5.93 |
| Marital statusb   | 197 (51.4) | 186 (48.6) | 383 (91.2) |
| Single            | 197 (51.4) | 186 (48.6) | 383 (91.2) |
| Married           | 13 (35.1) | 24 (64.9) | 37 (8.8) |
| State of originb  | 39 (51.3) | 37 (48.7) | 76 (18.2) |
| Abia              | 39 (51.3) | 37 (48.7) | 76 (18.2) |
| Anambra           | 37 (41.5) | 24 (58.5) | 61 (14.8) |
| Ebonyi            | 4 (44.4) | 5 (55.6) | 9 (2.1) |
| Enugu             | 5 (29.4) | 12 (70.6) | 17 (4.0) |
| Imo               | 145 (52.3) | 132 (67.7) | 277 (66.0) |
| Academic qualificationb | 2 (66.7) | 6 (33.3) | 8 (1.9) |

Data are provided as ‘mean±SD’ or ‘frequency (%). SD – Standard deviation
(186; 48.6%) were single while the rest, married (22.77%) at the time of the study. Moreover, 86.9% (365) of the population had above secondary education [Table 1].

The mean ± SD values of the right (R) toes (big toe or first toe [1T] to the fifth toes [5T]) for the male were 49.63 ± 4.43 mm (1T), 36.92 ± 5.14 mm (2T), 30.35 ± 4.95 mm (3T), 25.55 ± 3.97 mm (4T), and 22.21 ± 2.94 mm (5T), whereas the female values were 45.73 ± 4.07 mm (1T), 33.31 ± 4.66 mm (2T), 26.63 ± 4.02 mm (3T), 22.89 ± 3.43 mm (4T), and 19.77 ± 2.70 mm (5T) [Table 2].

The mean ± SD of the left (L) toes (big [1T] to the fifth toes [5T]) for males 49.16 ± 4.32 mm (1T), 36.82 ± 5.16 mm (2T), 30.88 ± 4.91 mm (3T), 26.13 ± 3.99 mm (4T), and 22.46 ± 3.24 mm (5T), whereas the female values were 45.33 ± 4.05 mm (1T), 33.05 ± 4.70 mm (2T), 27.27 ± 4.29 mm (3T), 23.10 ± 3.36 mm (4T), 19.81 ± 2.59 mm (5T) [Table 2].

The right toe values for the 1T and 2T were larger than those left in both sexes with MD ± standard error of T1 = 0.719 ± 0.487 mm for males and 0.404 ± 0.396 mm for females, T2 = 0.102 ± 0.502 mm for males and 0.257 ± 0.457 mm for females, whereas the left side of T3 and T4 were larger than the right in both sexes (T3 = 0.529 ± 0.481 mm for males, 0.642 ± 0.406 mm for females). The male left side was larger than the right for T5 (T4 = 0.125 ± 0.319 mm), whereas female had a relatively equal length for 5T (0.051 ± 0.294 mm) [Table 3].

The right toe values for the 1T and 2T were larger than those left in both sexes with MD ± standard error of T1 = 0.719 ± 0.487 mm for males and 0.404 ± 0.396 mm for females, T2 = 0.102 ± 0.502 mm for males and 0.257 ± 0.457 mm for females, whereas the left side of T3 and T4 were larger than the right in both sexes (T3 = 0.529 ± 0.481 mm for males, 0.642 ± 0.406 mm for females). The male left side was larger than the right for T5 (T4 = 0.125 ± 0.319 mm), whereas female had a relatively equal length for 5T (0.051 ± 0.294 mm) [Table 4].

### Table 2: Anthropometric characteristics of the measured foot dimension (toe length)

| Parameter | Sex | Right foot (mm) | Left foot (mm) |
|-----------|-----|----------------|----------------|
|           | R.T | L.T            | R.T            | L.T            |
| Mean±SD   | 49.63±4.43 | 36.92±5.14 | 30.35±4.95 | 25.55±3.97 | 22.21±2.94 | 45.73±4.07 | 33.31±4.66 | 26.63±4.02 | 22.89±3.43 | 19.77±2.70 |
| SE        | 0.31 | 0.35           | 0.34           | 0.27           | 0.2          | 0.3          | 0.36          | 0.34           | 0.28          | 0.22          |
| Minimum   | 38.69 | 25.15         | 19.09          | 16.49          | 15.44        | 39.86        | 21.46          | 16.64          | 16.78          | 15.19          |
| Maximum   | 66.06 | 54.34         | 50.97          | 37.5           | 31.83        | 60.08        | 50.61          | 47.57          | 38.69          | 38.89          |

### Table 3: Comparative (t-test) analysis of measured toe length (by side)

| Parameter by sides (mm) | df | t    | P      | Inference | MD ± SED | 95% CI of the difference |
|-------------------------|----|------|--------|-----------|----------|-------------------------|
|                         |    |      |        |           |          | Lower                   |
|                         |    |      |        |           |          | Upper                   |
| T1                      | 418| 1.477| 0.140  | NS        | 0.719   | 0.487                   |
| Male (right vs. left)   | 418| 1.019| 0.309  | NS        | 0.404   | 0.396                   |
| Female (right vs. left) | 418| 0.203| 0.839  | NS        | 0.102   | 0.502                   |
| T2                      | 418| 0.563| 0.574  | NS        | 0.357   | 0.457                   |
| Male (right vs. left)   | 418| 0.28 | 0.769  | NS        | 0.125   | 0.294                   |
| Female (right vs. left) | 418| 0.158| 0.114  | NS        | 0.642   | 0.406                   |
| T3                      | 418| -1.099| 0.272 | NS        | -0.529  | 0.481                   |
| Male (right vs. left)   | 418| -1.582| 0.114 | NS        | -0.642  | 0.406                   |
| Female (right vs. left) | 418| -1.582| 0.114 | NS        | -0.642  | 0.406                   |
| T4                      | 418| -1.485| 0.138 | NS        | -0.577  | 0.388                   |
| Male (right vs. left)   | 418| -0.588| 0.557 | NS        | -0.205  | 0.348                   |
| Female (right vs. left) | 418| -0.588| 0.557 | NS        | -0.205  | 0.348                   |
| T5                      | 418| -0.392| 0.695 | NS        | -0.125  | 0.319                   |
| Male (right vs. left)   | 418| 0.174| 0.862  | NS        | 0.051   | 0.294                   |
| Female (right vs. left) | 418| 0.174| 0.862  | NS        | 0.051   | 0.294                   |

df – Degree of freedom; t – T-test calculated value; P – Probability value; MD – Mean difference; SED – Standard error of the difference; CI – Confidence interval; S – Significant; NS – Not Significant.
Levene’s analysis of variance in mean showed that 
R.3T (F > 3.363, P = 0.067), R.4T (F > 5.704; P = 0.017) 
[Figure 1], and L.4T (F > 5.888; P = 0.016) had varied 
significantly in both sex which prompted the assumption of 
equal variance analysis of MD for the aforementioned 
variables, whereas for others, equal variances were 
assumed. The t-test analysis of MD revealed significantly 
higher mean values for males when compared to females 
for all measured toe length (t > 7.00; P < 0.01) [Table 5]. 
Graphical illustration of the changes in mean values of the 
toe in both sexes is highlighted in Figure 2.

The DFA was carried out using parameters that exhibited 
significant difference. The test of equality of group means 
in Table 5 indicates significant difference in the mean values 
of males and female (P < 0.001). Table 6 Box’s M tests null 
hypothesis of equal population covariance matrices. The 
canonical correlation is the multiple correlations between 
the predictors and the discriminant function. With only 
one function, it provides an index of overall model fit, 
which is interpreted as being the proportion of variance 
explained (R²). A canonical correlation of 0.491 suggests 
the model explains 23.24% of the variation in the grouping 
variable (that is; whether a value is male or female). Table 7 
reveals that all the predictors add some predictive power to 
the discriminant function as all are statistically significant 
with P < 0.001.

These unstandardized coefficients (b) in Table 8 are used to 
create the discriminant function (equation). It operates just 
like a regression equation. In this case, we have [Table 8]: 
D = (0.097 × R.1T) + (0.137 × R.5T) + (0.076 × R.3T)

Table 4: Comparative (t-test) analysis of measured toe length (by gender)

| Parameters | Levene’s test for equality of variances | T-test for equality of means | 95% CI of difference |
|------------|----------------------------------------|----------------------------|----------------------|
|            | F           | P          | Inference | df  | t     | P       | Inference | MD | SED | Lower | Upper |
| Age (years) | 0.829       | 0.047      | EVA       | 418 | 1.227 | 0.221   | NS        | 0.71 | 0.58 | -0.43 | 1.85  |
| Right T1 (mm) | 1.126       | 0.289      | EVA       | 418 | 9.390 | <0.01   | S         | 3.90 | 0.42 | 3.08  | 4.72  |
| Right T2 (mm) | 2.160       | 0.142      | EVA       | 418 | 7.549 | <0.01   | S         | 3.61 | 0.48 | 2.67  | 4.55  |
| Right T3 (mm) | 3.630       | 0.067      | EVNA      | 401 | 8.475 | <0.01   | S         | 3.73 | 0.44 | 2.86  | 4.59  |
| Right T4 (mm) | 5.704       | 0.017      | EVNA      | 409 | 7.352 | <0.01   | S         | 2.66 | 0.36 | 1.95  | 3.37  |
| Right T5 (mm) | 1.721       | 0.190      | EVA       | 418 | 8.859 | <0.01   | S         | 2.44 | 0.28 | 1.90  | 2.98  |
| Left T1 (mm) | 1.376       | 0.241      | EVA       | 418 | 9.379 | <0.01   | S         | 3.83 | 0.41 | 3.07  | 4.63  |
| Left T2 (mm) | 1.772       | 0.184      | EVA       | 418 | 7.821 | <0.01   | S         | 3.77 | 0.48 | 2.82  | 4.71  |
| Left T3 (mm) | 2.252       | 0.134      | EVA       | 418 | 8.032 | <0.01   | S         | 3.62 | 0.45 | 2.73  | 4.50  |
| Left T4 (mm) | 5.888       | 0.016      | EVNA      | 406 | 8.420 | <0.01   | S         | 3.03 | 0.36 | 2.33  | 3.74  |
| Left T5 (mm) | 3.739       | 0.054      | EVA       | 418 | 9.282 | <0.01   | S         | 2.66 | 0.29 | 2.09  | 3.22  |

Table 5: Table tests of equality of group means

| Parameters | Wilks’ lambda | F   | dfs | df2 | Significant |
|------------|---------------|-----|-----|-----|-------------|
| Right T1 (mm) | 0.826 | 88.174 | 1   | 418 | <0.001 | Significant |
| Right T2 (mm) | 0.880 | 56.991 | 1   | 418 | <0.001 | Significant |
| Right T3 (mm) | 0.853 | 71.819 | 1   | 418 | <0.001 | Significant |
| Right T4 (mm) | 0.886 | 53.536 | 1   | 418 | <0.001 | Significant |
| Right T5 (mm) | 0.841 | 78.802 | 1   | 418 | <0.001 | Significant |
| Left T1 (mm) | 0.878 | 57.984 | 1   | 418 | <0.001 | Significant |
| Left T2 (mm) | 0.893 | 49.986 | 1   | 418 | <0.001 | Significant |
| Left T3 (mm) | 0.866 | 64.508 | 1   | 418 | <0.001 | Significant |
| Left T4 (mm) | 0.856 | 70.341 | 1   | 418 | <0.001 | Significant |
| Left T5 (mm) | 0.861 | 67.507 | 1   | 418 | <0.001 | Significant |

Table 6: Table tests of equality in population covariance matrices and canonical correlation

| Box’s M equality in covariance | Eigen value | Canonical correlation |
|-------------------------------|-------------|-----------------------|
| Values                        | Eigen value | Canonical correlation |
|                              |             |                       |
| Box’s M F                     | 230.5338086 |                       |
| Approximately df1            | 4.086737342 | 1                     |
| df2                           | 564.238056  | 0.318                 |
| Significant                   | <0.0001     | 0.491                 |

Table 7: Wilks’ lambda test for predictability into group membership

| Test of function (s) | Wilks’ lambda | χ² | df | P   | Inference |
|----------------------|---------------|----|----|-----|-----------|
| 1                    | 0.759         | 133.892 | 6 | <0.001 | Significant |
Table 8: Canonical discriminant function coefficient structured, standardized, and unstandardized

| Box's M structure Matrix coefficients | Standardized canonical discriminant function coefficients | Unstandardized canonical discriminant function coefficients |
|--------------------------------------|--------------------------------------------------------|----------------------------------------------------------|
| Variables                            | Functiona                                           | Function                                                | Functiona                                           |
| Right T1                             | 0.815**                                              | 0.423                                                   | 0.097                                                |
| Right T5                             | 0.771**                                              | 0.398                                                   | 0.337                                                |
| Right T3                             | 0.736**                                              | 0.344                                                   | 0.076                                                |
| Left T4                              | 0.728**                                              | 0.119                                                   | 0.032                                                |
| Left T5                              | 0.713**                                              | 0.269                                                   | 0.080                                                |
| Left T3                              | 0.637**                                              | 0.304                                                   | 0.022                                                |
| Left T1                              | 0.661**                                              | 0.099                                                   | 0.020                                                |
| Right T2                             | 0.635**                                              | 0.003                                                   | 0.001                                                |
| Right T4                             | 0.635*                                                | -0.409                                                  | -0.108                                               |
| Left T2                              | 0.614*                                                | -0.092                                                  | -0.017                                               |
| Constant                             |                                                        |                                                        | -10.572                                              |

Variables that are making: **strong predictions; *average prediction. a Function - Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions; b Function - Coefficients used for computing group membership value.

Table 9: Functions at group centroids

| Sex | Functiona |
|-----|------------|
| Male| 0.562      |
| Female| -0.562   |

aUnstandardized canonical discriminant functions evaluated at group means.

Table 10: Classification function coefficients

| Sex | Male | Female |
|-----|------|--------|
| Right T1 (mm) | 1.913 | 1.804 |
| Right T2 (mm) | 0.200 | 0.199 |
| Right T3 (mm) | -0.003 | -0.088 |
| Right T4 (mm) | -0.357 | -0.436 |
| Right T5 (mm) | 1.019 | 0.865 |
| Left T1 (mm) | 0.730 | 0.707 |
| Left T2 (mm) | -0.110 | -0.090 |
| Left T3 (mm) | 0.116 | 0.091 |
| Left T4 (mm) | 0.078 | 0.058 |
| Left T5 (mm) | 0.413 | 0.322 |
| Constant | -76.320 | -64.424 |

Table 11: Percentage predictability for group membership

| Prediction (%) | Sex | Predicted group membership | Total |
|----------------|-----|----------------------------|-------|
|                | Male| Female                     |       |
| Originala      | 152 (72.4) | 58 (27.6)               | 210 (100) |
| Cross-validatedb | 145 (69.0) | 65 (31.0)               | 210 (100) |

| Sex | Predicted group membership | Total |
|-----|----------------------------|-------|
| Male| 61 (29.0)               | 147 (70.0) |
| Female| 145 (69.0) | 65 (31.0) |

Results of each group can further be described in terms of its profile using the group means of the predictor variables. These group means are called centroids. These are displayed in the group centroids [Table 9]. In this study, the males have a mean of 0.562, whereas female produce a mean of 0.562. Cases with scores near to a centroid are predicted as belonging to that group.

The coefficients of linear discriminant function which is also called “classification functions,” in Table 10 interprets the Fisher’s theory for each observation, have following form $P_k = P_{k0} + P_{k1}X_1 + P_{k2}X_2 + ... + P_{km}X_m$. Where, $P_k$ is the classification score for group $k$ and $P_{km}$ are the coefficients in Table 10. For one observation, we can compute its score for each group by the coefficients according to equation (above).

Table 5 shows the level of difference in the observed values of males and females with $P < 0.01$ indicating a statistically significant difference. The Box’s $M$ covariance matrix showed inequality in the group variance did not meet the assumption of equal group variance, which indicates a larger discrepancy in the predictor variables. The magnitude of the actual effect of the predictors (canonical coefficient) and the outcome is the square of the coefficient (0.491); this indicates that the relationship between the predictor variable and the prediction outcome is 0.232 which suggests the model explains 23.24% of the variation in the grouping variable, that is, whether the values are male or female [Table 6]. However, the
group of predictor variables (R.1T, R.2T, R.3T, R.4T, R.5T, L.1T, L.2T, L.3T, L.4T, and L.5T) will make predictions that are statistically significant in their outcomes (Wilk’s lambda = 0.759, \( P < 0.001 \)) [Table 7], as the variables that seems to have the highest predictor capability which can be used to classify into group membership are R.1T (0.82), R.5T (0.77), R.3T (0.74) with other values falling between 0.70 and 0.66 [Table 8].

The classification results [Table 11] reveal that 72.6% of toe measurements were classified correctly into “male” or “female” groups using the various parameters; upon cross validation, accurate prediction fell to 69.5%. This overall predictive accuracy of the discriminant function is called the “hit ratio.” Upon reclassification, what is an acceptable hit ratio? You must compare the calculated hit ratio with what you could achieve by chance. If two samples are equal in size, then you have a 50/50 chance anyway. This research would accept a “hit ratio” that is 30% larger than that due to chance.

**DISCUSSION**

Forensic anthropometry will require series of systematized measuring techniques that express quantitatively the dimensions of the human body and skeleton\(^1\)\(^6\) in order to present findings as evidences in the course of any investigation. Some authors have used fragments of the long bones; upper or lower end to evaluate sex.\(^1\)\(^3\) Most of the time, long bones have been used in the determination of stature because they relatively give more accurate prediction.\(^1\)

Sex is considered as one of the easiest determinations from the skeletal material and one of the most reliable if essential parts of the skeleton are available in good condition.\(^5\)\(^6\) The most often chosen bones for the determination of sex are the pelvis and the skull although the round heads of the ball joints also provide very reliable means of determining sex.\(^7\)\(^8\) Sex determination is also supposed to be reliable when up to 95% accuracy can be achieved.\(^6\)\(^8\)

There are remarkable scholarly publications on the sexual dimorphic characteristics of the hand bones;\(^17\)\(^18\) noteworthy is the use of the 2\(^{nd}\) digit: 4\(^{th}\) digit ratio\(^19\)\(^21\) with its dimorphic characteristics attributed to hormonal difference.\(^22\)\(^23\) However, such cannot be said about the toe as successive decrease in toe length was observed (1T–5T).

Research on the use of toe length to differentiate sex is rather scarce; thus, making this study a pioneer one. Indications from the analysis highlights nonsymmetric difference in toe length with significant sex-related anthropometric difference in all toes (1T–5T). From the difference observed in toe measurements, there may be indication of foot dominance correlating with big toe length in association with foot length; as the right big toe (1T) was larger than the left in most subjects, whereas the reverse was observed for the third toe (3T), fourth toe (4T); and small toe (5T) in males. The graphical illustration shows how the MDs in both sexes changes with toe; indicating sex discrimination.

The use of DFA was to evaluate the accurateness and predictability of the model using the observed significant measured variables. The strength of such model is the ability to classify above 80% of the measured parameters into groups (sex) although a 95% accuracy bench mark have been established.\(^6\)\(^8\)

The model accuracy for discriminant model for sex categorization in this study seems quite low; although with a better prediction for female (70%) than males (69%). This result indicates caution prediction into group membership using this model taking into consideration; errors (\(e\)) which may have occurred that resulted in the deviation from high discrimination.

**CONCLUSION**

Evidence from this study clearly indicates sex-associated difference in foot parameters. DFA successfully predicted 69.5% of the data into groups (sex) and the prediction statistically significant; thus suggestive of forensic attributes. However, such predictive value seems quite low; hence, the use of toe dimensions alone may not be effective for sex differentiation. The findings argue that a single set of foot dimensions may not be applicable in sex grouping. Therefore, toe length can serve as adjunct in sex identification.

**Financial support and sponsorship**

Nil.

**Conflicts of interest**

There are no conflicts of interest.

**REFERENCES**

1. Krishan K. Anthropometry in forensic medicine and forensic science ‘forensic anthropometry’. The internet. J Forensic Sci 2006;2:10-5.
2. Gopichand PV, Kaushal S, Kaur G. Personal identification using lip prints (chelioscopy) – A study in 500 Punjabi females. J Ind Pac Acad Forensic Odont 2009;1:20-2.
3. Kanchan T, Krishan K. Anthropometry of hand in sex determination of dismembered remains – A review of literature. J Forensic Leg Med 2011;18:14-7.
4. Pekka S, Knights B. Forensic Pathology, Infanticide, Still Birth and Fatal Child Abuse. 3\(^{rd}\) ed. London: Edward Arnold (Publisher) Ltd.; 1996. p. 460-1.
5. Krogman WM, Iscan Y.M. The Human Skeleton in Forensic Medicine. 2\(^{nd}\) ed. Springfield, Illinois, U.S.A.: Charles C. Thomas Pub Ltd.; 1986. p. 30-5.
6. Iscan MY. Forensic anthropology of sex and body size. Forensic Sci Int 2005;147:107-12.
7. Iscan MY, Miller-Shaivitz P. Determination of sex from the
tibia. Am J Phys Anthropol 1984;64:53-7.
8. Iscan MY, Shihaia D. Sexual dimorphism in the Chinese femur. Forensic Sci Int 1995;74:79-87.
9. Bainbridge D, Santiago GT. A study of the sex differences in the scapula. J R Anthropol Inst 1956;86:109-34.
10. Di Vella G, Campobasso CP, Dragone M, Introna F Jr. Skeletal sex determination by scapular measurements. Boll Soc Biol Sper 1994;70:299-305.
11. Ibeachu PC, Aigbogun E Jr., Didia BC, Fawehinmi HB. Determination of sexual dimorphism by odontometric study using discriminant function analysis of adult Ikwerre dental cast. SJAMS 2015;3:1732-8.
12. Fisher RA. The statistical utilization of multiple measurements. Ann Eugen 1936;8:376-86.
13. Fisher RA. The precision of discriminant function. Ann Eugen 1940;10:422-9.
14. Cochran WG. Sampling Techniques. 2nd ed. New York: John Wiley and Sons, Inc.; 1963. p. 2-5.
15. Yamane T. Statistics – An Introductory Analysis. 2nd ed. New York: Harper and Row; 1967. p. 15-20.
16. Douglass H, Ubelakers S. Anthropology and medicine. Introd Forensic Anthropol 2006;3:12.
17. Lippa RA. Are 2D: 4D finger-length ratios related to sexual orientation? Yes for men, no for women. J Pers Soc Psychol 2003;85:179-88.
18. Eshak GA, Ahmed HM, Abdel Gawad EA. Gender determination from hand bones length and volume using multidetector computed tomography: A study in Egyptian people. J Forensic Leg Med 2011;18:246-52.
19. Manning JT, Scutt D, Wilson J, Lewis-Jones DI. The ratio of 2nd to 4th digit length: A predictor of sperm numbers and concentrations of testosterone, luteinizing hormone and oestrogen. Hum Reprod 1998;13:3000-4.
20. Oladipo GS, Olotu EJ, Gwunireama IU. Second to fourth digit ratio (2D: 4D) of Igbos and Urhobos. J Biomed Afric 2006;4:53-4.
21. Gwunireama IU, Ihemelandu EC. Geographical influence of digit ratio (2D: 4D): A case study of Andoni and Ikwerre ethnic groups in Niger Delta, Nigeria. J App Biosci 2010;27:1736-5.
22. Wang Y. Is obesity associated with early sexual maturation? A comparison of the association in American boys versus girls. Pediatrics 2002;110:903-10.
23. Lutchmaya S, Baron-Cohen S, Raggatt P, Knickmeyer R, Manning JT. 2nd to 4th digit ratios, fetal testosterone and estradiol. Early Hum Dev 2004;77:23-8.