***Title***

***Determination of sex from discriminant function analysis (DFA) of Shoe and Footprints dimensions amongst adults of Cross River State, Nigeria.***

***names arranged in order of first, second and Surname respectively.***

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**Abstract**

Impressions of shoe and footprints are commonly found in crime scenes. Examination of these prints provide useful insight in crime scene investigation.

This study attempts to determine gender using shoe and footprints dimensions by deriving discrimination models.

A total sample size of 260 subjects, (145 females and 115 males) of adult, were taken. Shoe and footprints were taken using inkpad, containing removable ink. Each subject was asked to carefully step on the inkpad and placed it on the plane A4 sheet of paper to make shoe and foot outline. Followed by shoe and footprint dimensions measurement, first by highlighting the various landmarks of foot length and breadth.

This results showed that shoe and footprints dimensions recorded statistical significant difference (p < 0.05) as seen in the outcome of independent sample t-test for sexual dimorphism for right shoe and footprints. Moreso, the analysis of paired sample test between the left and right shoe and footprints dimensions showed statistical significant difference (P<0.05) in most of the parameters except LT3, LT4 and LT5.

Group centroids which is a function of group membership with cut off functions for the males and females are 0.650 and -5.16 respectively, canonical discriminant function showed skewness with a cluster of the male and female determine sex tilting to the opposite direction respectively.

This present study has demonstrated the utility and precision of sex determination models developed from shoe and footprints dimensions. Therefore, this study has provided a baseline data upon which further studies will thrive. Moreso, this data will be useful to a forensic expert saddled with investigations involving human identity.

Key Words: Forensic Science, Discriminant Function Analysis, Sex Determination.

**INTRODUCTION**

Determination of personal identity is the first and the most important step in medico-legal practice and forensic investigations. [1-4] In most forensic cases, human identification is generally carried out through examination of the body or the remains (or prints) from the body. Thus, the shoe and footprints become extremely significant, especially when a body is incomplete or unavailable. [3-6] The human foot is a highly complex structure consisting of 26 major bones and numerous synovial joints[7] It plays a role in both load support and shock absorption as well as providing balance and stabilization of the body during gait.[7-8] The shape and structure of human foot varies considerably due to the combined effects of heredity, lifestyle, and environmental factors.[9] In addition, natural biological variance, age, population group, BMI, parity and sex have immense influences on the shape and structure of an individual’s foot.[10] Sex differences in foot morphology have important applications in footwear design.[10-12] Some authors have reported that in mass disasters such as aircraft crashes, explosions, and warfare, body particles and extremities are often the only remains recovered.[13-14] Therefore, it can be questioned whether feet and particles torn out of feet have the potential to help in the positive identification of the deceased people. A lot of literature exist on the determination of body height via foot measurements and other body segments in forensic sciences.[15-19] However, it has not been sufficiently established whether sex can be ascertained through the analysis of a shoe, foot or of a partial foot torn off the body.[11&20] Some studies even reported that contact area at any region of the plantar surface of the foot is greater in men than in women.[21-22]

A footprint is an impression of the weight-bearing areas of the plantar surface of the foot.[23] Footprints can be found on rain covered surfaces, newly waxed floors, freshly cemented surfaces, moistened surfaces, in dust, mud, sand, oil, paint and blood at murder scenes[23-24]

Even though current forensic scientists perform comprehensive chemical and physical analyses of biological evidence (Hair strands, Blood stain, sweat, saliva etc) found on the crime scene, as their work is often instrumental in apprehending and convicting criminals. However, it is still very pertinent to focus on other physical and miscellaneous evidences with the increasing sophistication of crimes, investigation need to be heightened to employ footprints, handwriting comparisons to determine a valid civil justice system. The application of new technology to criminal and civil investigations has the effect of extending the limits of physical evidence [25-26]. From this evolution of criminal investigation procedures has come a greater need for well-trained forensic scientists as well as initiatives for developing innovative approaches to educating students in science [27]

Shoes and foot prints found in the vicinity of the incidences may also play an important role in the identification of unknown persons. A couple of results have been published on the determination of identity from the individualizing characteristics of foot prints.[28-31] Yet, the number of studies to estimate sex through shoe dimensions is extremely limited.[20] Footprints can be found at crime scenes because offenders often remove their footwear, either to avoid noise or to gain a better grip in climbing walls, etc, while entering or exiting.[32] Like fingerprints, footprints of an individual are unique to that individual.[18, 32-33] Hence, footprints linked to a crime can be compared with a suspect’s footprints as a means of confirming or ruling out involvement in that crime. The shape of a footprint is influenced by a complex of anatomical, functional, and sedimentary (surface) variables.[34] The depth of a footprint varies with plantar pressure distribution depending on the nature and type of the substrate.[27&34] Therefore, sex differences in plantar contact area and plantar pressure distribution imply sex differences in footprint morphology. Several studies support the existence of dimensional sexual dimorphism in footprint morphology [30]

The discriminant functions developed from shoe and footprints data for a particular population cannot be applied universally since people from different populations differ in their foot morphology; population-specific standards are necessary for accurate sex determination. Presently there is dearth of data in Cross River State population in particular and paucity of result in Nigeria at large for determination of sex from shoe and footprints dimensions. This preliminary study, therefore, sought to verify the utility and reliability of footprint dimensions in sex determination, and establish population-specific discriminant functions for sex determination in a cross river adult.

**MATERIALS AND METHOD**

***Materials used***

The materials, which are used for this study include: Foot ink pad for obtaining the outline of the shoe and footprints, removable ink for colour contrast patent print on the white paper, meter rule for measurement of the length and breadth of the print dimensions, A4 plain paper to bear the outline of the prints, pen to record demographic bio-data of the subjects, HB Pencil to draw the measured landmarks, Methylated Spirit to remove ink from the participants foot and shoe, Cotton wool for easy removal of the ink.

***Study Population***

This study involves male and females teenagers of cross river state. Cross River State. Cross River State is a costal state in south-south part of Nigeria. It is located in the Niger Delta and it is popular called the peoples paradise (Calabar). It shares boundaries with Benue state to the north, Abia and Ebonyi state to the west, Cameroon Republic to the east, and to the South by Akwa Ibom state. Cross River State occupies a landmark of 2,156 sq. km (7,782sq. meters). The estimated population size of Cross River State for 2006 is 2,888,966 (2006 census figures) and the population density varies from 93km sq. (240 sq. meters). It has a coordinate of latitude 2\*45’N and longitude of 8\*30’E, Cross river State for is composed of 3 major ethnic groups: The Efik, the Ejagham and the Bekwarra, and it is divided into 18 local Governments. The most predominantly spoken language in Cross River is Ejagham and Efik. Efik is one of the largest ethnic groups in Cross river State with a total estimated population of 634, 4000 people.

***Study Design***

The study population comprised of randomly selected Cross River State adults that resides within the 18 local government areas of the state. The study participants were drawn from the three major ethnic groups of the state (Ejagham, Efik and the Bekwarra). A total sample size of 260 (115males and 145females), aged 18-45 years were engaged for this research with full consent upon conviction of the research protocol and possible benefits and sign informed consent form. Also subjects’ participation was based upon meeting the inclusion criteria.

The shoe and footprint were obtained from the left and right feet of the sample population. First, the black coloured indelible endorsing ink was poured into the foot ink pad, the subjects were then asked to step on the ink pad which already contains the endorsing ink, after which they were directed to place the inked foot firmly on the white duplicating A4 papers attached to the flat wooden board lying on the ground surface. Afterwards, the soles of the feet of each subjects were washed with soap and water and sometimes methylated spirit To establish a definite axial orientation for measurement, two important landmarks- the designated longitudinal axis (DLA) and base line (BL) - were marked on the footprint following procedures describe by Krishan *et al.*, (2012). The DLA was drawn as a straight line from the pterion (i.e the most posterior point of the rear heel margin) to the lateral side of the first toe pad margin. Base line (BL) was drawn perpendicular to the DLA at the rear edge of the footprint, extending from the pterion in both medial and lateral directions. The following measurements were taken on each footprint

***Inclusion/ exclusion criteria***

Those to be recruited from this research exercise include;

* People within the age of 18 to 45.
* Subject whose both parents are from Cross River State and equally residing in the state
* Subjects with hand or foot malformations like club foot, polydactyl, amputated hands, waiters tip etc, were excluded.

***Demographics***

Sampling variables including gender, age, and tribe, side of shoe and footprint dimensions were recorded on the top left corner of the plain sheet.

**Statistical Analysis**

The data acquired were subjected to series of analyzed using Statistical Package for Social Sciences (SPSS) software version 20, Chicago Inc. for Descriptive statistics was employed and presented as Mean±SD, Independent and paired sample t-test were equally engaged to ascertain sexual dimorphism at (p<0.01), discriminant function analysis was employed to predict sex with different cut off between the males and female.

**Results**

This data gotten from a cross-sectional study of adults Cross Riverians was analysed using statistical package for social sciences (SPSS) version 21. Chicago incorporated. The statistical tools employed for this analysis include Chi square for frequency distribution between males and females subjects, Descriptive Statistics to show the mean, maximum, minimum and standard error of means. Independent sample T-test was carried out for sex differences and discriminant function analysis (DFA) was done for sex determination and all data are presented in tables and graphs.

**Table 1-showing the results of descriptive statistics of the male and female right shoe and footprint dimensions**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **PARAMETERS** | **MALE**  **N=115** | | | | **FEMALE**  **N=145** | | | |
| **Mean±SD** | S.E | MIN | MAX | **Mean±SD** | S.E | MIN | MAX |
| **RT1 (Cm)** | **24.10±1.3** | 0.126 | 20.80 | 28.00 | **24.50±1.7** | 1.444 | 20.30 | 32.20 |
| **RT2 (Cm)** | **23.76±1.3** | 0.125 | 19.40 | 27.20 | **22.73±1.3** | 0.115 | 19.30 | 26.40 |
| **RT3 (Cm)** | **22.89±1.3** | 0.125 | 18.70 | 26.70 | **21.91±1.3** | 0.112 | 18.10 | 25.30 |
| **RT4 (Cm)** | **21.86±1.0** | 0.128 | 17.80 | 25.0 | **20.91±2** | 0.104 | 17.60 | 23.80 |
| **RT5 (Cm)** | **20.42±1.3** | 0.128 | 16.60 | 24.10 | **19.55±1.3** | 0.108 | 16.60 | 22.70 |
| **RBAB (Cm)** | **9.53±0.8** | 0.076 | 7.90 | 11.70 | **9.76±7.1** | 0.596 | 6.00 | 15.00 |
| **RBAH (Cm)** | **6.18±4.6** | 0.434 | 3.80 | 5.00 | **5.51±0.7** | 0.061 | 4.10 | 8.00 |
| **RSL (Cm)** | **24.72±1.6** | 0.156 | 20.50 | 29.20 | **23.71±1.4** | 0.122 | 19.60 | 27.20 |
| **RSB (Cm)** | **9.49±0.8** | 0.081 | 7.10 | 11.50 | **8.80±0.8** | 0.071 | 7.10 | 11.40 |

**RT1= Right foot length at big toe, RT2= Right foot length at second toe, RT3= Right foot length at third toe, RT4= Right foot length at fourth toe, RT5= Right foot length at fifth toe, RBAB= Right breadth at ball, RBAH= Right breadth at hill, RSL= Right Shoe length, RSBRight shoe breadth**

**Table 2-showing the results of descriptive statistics of the male and female left shoe and footprint dimensions**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **PARAMETERS** | **MALE**  **N=115** | | | | **FEMALE**  **N=145** | | | |
| **Mean±SD** | S.E | MIN | MAX | **Mean±SD** | S.E | MIN | MAX |
| **LT1 (Cm)** | **24.23±1.41** | 0.13 | 20.90 | 27.70 | **23.12±1.2** | 0.101 | 20.10 | 26.30 |
| **LT2 (Cm)** | **23.85±1.4** | 0.135 | 19.60 | 27.90 | **24.13±1.5** | 1.327 | 19.20 | 24.50 |
| **LT3 (Cm)** | **23.05±1.3** | 0.130 | 19.20 | 26.80 | **21.95±1.3** | 0.111 | 18.00 | 24.90 |
| **LT4 (Cm)** | **21.99±1.3** | 0.129 | 18.60 | 25.50 | **20.961±1.3** | 0.109 | 17.90 | 24.50 |
| **LT5 (Cm)** | **20.59±1.3** | 0.124 | 17.50 | 23.70 | **19.602±1.3** | 0.115 | 17.00 | 24.70 |
| **LBAB (Cm)** | **9.50±0.8** | 0.075 | 7.80 | 11.70 | **9.147±0.8** | 0.066 | 6.10 | 11.00 |
| **LBAH (Cm)** | **6.28±4.7** | 0.442 | 4.50 | 56.00 | **5.587±0.7** | 0.060 | 3.80 | 8.00 |
| **LSL (Cm)** | **24.76±2.0** | 0.194 | 10.40 | 28.6 | **23.770±1.5** | .1249 | 19.00 | 27.90 |
| **LSB (Cm)** | **9.53±1.6** | 0.158 | 7.30 | 25.10 | **8.74±0.8** | 0.072 | 6.00 | 11.00 |

**LT1= Leftt foot length at big toe, LT2= Left foot length at second toe, LT3= Leftt foot length at third toe, LT4= Leftt foot length at fourth toe, LT5= Leftt foot length at fifth toe, LBAB= Left breadth at ball, LBAH= Leftt breadth at hill, LSL= Leftt Shoe length, LSB Leftt shoe breadth**

**Table 3-showing the results of descriptive statistics of the left and right shoe and footprint dimensions of total sample size**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **variables** | **Left Shoe and footprints dimension of Total sample**  **N=260** | | | | **Right Shoe and footprints dimension of total sample**  **N=260** | | | |
|  | **Mean±SD** | S.E | MIN | MAX. | **Mean±SD** | S.E | MIN | MAX |
| T1 | **23.61±1.4** | 0.088 | 20.1 | 27.70 | **24.32±1.3** | 0.806 | 20.30 | 32.0 |
| T2 | **24.00±11.9** | 0.741 | 19.2 | 24.50 | **23.19±1.4** | 0.090 | 19.30 | 27.2 |
| T3 | **22.44±1.4** | 0.091 | 18.0 | 26.80 | **22.35±1.4** | 0.088 | 18.10 | 26.7 |
| T4 | **21.41±1.4** | 0.089 | 17.9 | 25.50 | **21.3±1.3** | 0.086 | 17.60 | 25.0 |
| T5 | **20.02±1.4** | 0.089 | 17.0 | 24.70 | **19.94±1.4** | 0.087 | 16.60 | 24.1 |
| BAB | **9.30±0.8** | 0.050 | 6.10 | 11.70 | **9.66±5.3** | 0.334 | 6.00 | 15.0 |
| BAH | **5.89±3.2** | 0.199 | 3.80 | 56.00 | **5.80±3.1** | 0.195 | 3.80 | 8.0 |
| SL | **24.21±1.8** | 0.114 | 10.40 | 26.28 | **24.16±1.6** | 0.102 | 19.60 | 29.2 |
| SB | **9.09±1.3** | 0.084 | 6.00 | 25.10 | **9.10±0.90** | 0.057 | 7.10 | 11.5 |

**Table 4 result of paired sample t-test for bilateral asymmetry between the left and right footprint dimensions**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| R-L | Difference in mean (Right-Left) | Std. Error of Mean | 95% Confidence Interval | | t-value | P-value |
| Lower | Upper |
| T1 | 0.713 | 0.805 | -0.871 | 2.299 | 0.887 | 0.376 |
| T2 | -0.812 | 0.744 | -2.278 | 0.653 | -1.092 | 0.276 |
| T3 | -0.091 | 0.044 | -0.179 | -0.004 | -2.060 | 0.040 |
| T4 | -0.081 | 0.046 | -0.173 | 0.009 | -1.760 | 0.080 |
| T5 | -0.101 | 0.046 | -0.193 | -0.010 | -2.183 | 0.030 |
| BAB | 0.036 | 0.332 | -0.294 | 1.014 | 1.083 | 0.280 |
| BAH | -0.088 | 0.270 | -0.620 | 0.444 | -0.326 | 0.745 |
| SL | -0.046 | 0.086 | -0.215 | 0.123 | -0.535 | 0.593 |
| SB | 0.010 | 0.070 | -0.127 | 0.148 | 0.148 | 0.883 |

***Shoe and footprint variables with P<0.05 are statistical significant different between the left and right hand.***

**Table 5- Results of Independent sample t-test for sexual dimorphism for measured left and right footprints dimensions**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Variables** | | **Mean Difference** | | **Std. Error** | **95% Confidence** | | **p-value** |
| **Lower** | **Upper** |
| **RIGHT** | | | | | | | |
| RTI | | -0.405 | | 1.626 | -3.608 | 2.797 | 0.803 |
| RT2 | | 1.030 | | 0.171 | 0.692 | 1.368 | 0.000 |
| RT3 | | 0.979 | | 0.168 | 0.647 | 1.311 | 0.000 |
| RT4 | | 0.957 | | 0.163 | 0.634 | 1.279 | 0.000 |
| RT5 | | 0.876 | | 0.167 | 0.546 | 1.204 | 0.000 |
| RBAB | | -0.231 | | 0.674 | -1.557 | 1.096 | 0.732 |
| RBAH | | 0.666 | | 0.393 | -0.107 | 1.440 | 0.091 |
| RSL | | 1.004 | | 0.196 | 0.617 | 1.390 | 0.000 |
| RSB | | 0.687 | | 0.107 | 0.475 | 0.899 | 0.000 |
| **LEFT** | | | | | | | |
| LT1 | 1.1020 | | 0.164 | | 0.7796 | 1.424 | 0.000 |
| LT2 | -0.2822 | | 1.496 | | -3.2275 | 2.663 | 0.851 |
| LT3 | 1.1001 | | 0.170 | | 0.7648 | 1.435 | 0.000 |
| LT4 | 1.0315 | | 0.168 | | 0.6998 | 1.363 | 0.000 |
| LT5 | 0.9953 | | 0.170 | | 0.6598 | 1.331 | 0.000 |
| LBAB | 0.3540 | | 0.100 | | 0.1565 | 0.551 | 0.000 |
| LBAH | 0.7001 | | 0.399 | | -0.0861 | 1.486 | 0.081 |
| LSL | 0.9947 | | 0.223 | | 0.5556 | 1.434 | 0.000 |
| LSB | 0.7905 | | 0.163 | | 0.4703 | 1.110 | 0.000 |

***Variables with P<0.05 are statistical significant different between the male and female.***

***TESTS OF EQUALITY OF GROUP MEANS***

Discriminant function analysis (DFA) was carried out using eighteen (18) parameters. In Table 6 the test of equality of mean difference for male and female values were carried out, with all the eighteen (18) entered into the model being significant (*P*< 0.001).

**Table 6- shows the result of discriminant function analysis (DFA) for sex determination**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Wilks' Lambda** | **F** | **df2** | **Sig. (P-value)** |
| RTI | 1.000 | 0.062 | 258 | <0.001\* |
| RT2 | 0.877 | 36.024 | 258 | <0.001\* |
| RT3 | 0.884 | 33.699 | 258 | <0.001\* |
| RT4 | 0.883 | 34.154 | 258 | <0.001\* |
| RT5 | 0.904 | 27.447 | 258 | <0.001\* |
| RBAB | 1.000 | 0.117 | 258 | <0.001\* |
| RBAH | 0.989 | 2.872 | 258 | <0.001\* |
| RSL | 0.908 | 26.181 | 258 | <0.001\* |
| RSB | 0.864 | 40.776 | 258 | <0.001\* |
| LT1 | 0.851 | 45.322 | 258 | <0.001\* |
| LT2 | 1.000 | 0.036 | 258 | <0.001\* |
| LT3 | 0.861 | 41.725 | 258 | <0.001\* |
| LT4 | 0.873 | 37.503 | 258 | <0.001\* |
| LT5 | 0.883 | 34.128 | 258 | <0.001\* |
| LBAB | 0.954 | 12.465 | 258 | <0.001\* |
| LBAH | 0.988 | 3.075 | 258 | <0.001\* |
| LSL | 0.928 | 19.896 | 258 | <0.001\* |
| LSB | 0.916 | 23.639 | 258 | <0.001\* |

*Shoe and footprint variable with Wik’s Lambda values having P<0.001 are good predictors of sex. Meaning this prediction using the measured variables has a confidence interval of prediction of about 99.999%*

***TESTS OF EQUALITY IN POPULATION COVARIANCE MATRICES AND CANONICAL CORRELATION***

The Box’s M test of equality in population, covariance matrices as well as the canonical correlation, provides an index of overall model fit. Significant difference (**p<0.001**) was observed in the Box’s M covariance matrix; hence equal group variance cannot be assumed. This suggests a larger discrepancy in the predictor variables. However, the magnitude or the actual effect size of the predictors (being the canonical coefficients) and the outcome becomes the square of the coefficient of the canonical correlation (0.803)2, suggests that the model can only explain 64.48% of the grouping (discriminating) variables (i.e. the sex of the individual).

**Table 7- presents the result of Tests of equality in population covariance matrices and canonical correlation**

|  |  |  |
| --- | --- | --- |
| **Test Results** | | |
| Box's M | | 3051.115 |
| F | Approx. | 16.527 |
| df1 | 171 |
| df2 | 183895.408 |
| Sig. | **0.001**\* |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Eigenvalues** | | | | |
| Function | Eigenvalue | % of Variance | Cumulative % | Canonical Correlation |
| 1 | 0.338a | 100.0 | 100.0 | **0.803** |

***WILKS' LAMBDA TEST FOR PREDICTABILITY INTO GROUP MEMBERSHIP***

Wilks' lambda test for predictability into group membership as presented showed that the predictor variables will make statistically significant predictions (Wilk’s lambda = 0.747, ***P*< 0.001**).

**Table 8- present Wilks' lambda test for predictability into group membership**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Wilks' Lambda** | | | | |
| Test of Function(s) | Wilks' Lambda | Chi-square | df | Sig. |
| 1 | 0.747 | 72.504 | 18 | **0.001**\* |

***CANONICAL DISCRIMINANT FUNCTION COEFFICIENT STRUCTURED, STANDARDIZED AND UNSTANDARDIZED***

The unstandardized coefficients used to generate the discriminant function equation. The discriminant function coefficient (unstandardized) indicates the partial contribution of each variable in the discriminant function equation. These values provide information on the relative importance of each variable and are therefore used to assess each individual’s variables unique contribution to the discriminant function equation.

**Table 9- shows results of 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 (cm)** | **Functiona** | Function | Functionb |
| LT1 | 0.721\*\*\* | -0.096 | -0.007 |
| LT3 | 0.692\*\*\* | -0.165 | -0.120 |
| RSB | 0.684\*\*\* | -0.532 | -0.394 |
| LT4 | 0.656\*\*\* | 0.547 | 0.417 |
| RT2 | 0.643\*\*\* | 0.062 | 0.046 |
| RT4 | 0.626\*\*\* | -0.133 | -0.025 |
| LT5 | 0.626\*\*\* | 0.053 | 0.017 |
| RT3 | 0.622\*\*\* | 0.019 | 0.012 |
| RT5 | 0.561\*\*\* | 0.370 | 0.429 |
| RSL | 0.548\*\*\* | 0.314 | 0.240 |
| LSB | 0.521\*\*\* | -0.022 | -0.002 |
| LSL | 0.478\*\* | 0.074 | 0.054 |
| LBAB | 0.378\*\* | -0.354 | -0.263 |
| LBAH | 0.188\*\* | 0.527 | 0.386 |
| RBAH | 0.181\*\* | 0.151 | 0.189 |
| RBAB | -0.037\* | 0.178 | 0.056 |
| RTI | -0.027\* | 0.281 | 0.157 |
| LT2 | -0.020\* | 0.345 | 0.265 |
| **Constant** |  |  | **-19.343** |
| **Variables with asterisk represents hierarchy of predictability strenght; \*\*\*strong predictions; \*\*average prediction; \*poor prediction.** | | | |

***FUNCTIONS AT GROUP CENTROIDS***

The group centroids (the group mean of the predictor variables), is a function of group membership or classification and also serves as a classification cut off thus a medium of discrimination. As observed, the males have a group mean of 0.650, while the females have a group mean of -0.516. Hence functions at group centroids with a group mean near to a centroid is predicted to belong to that group (i.e. close to 0.650 as male, while -0.516 as female).

**TABLE 10-** Shows the group centroids (the group mean of the predictor variables), is a function of group membership or classification and also serves as a classification cut off thus a medium of discrimination.

|  |  |
| --- | --- |
| SEX | Function |
| MALE | 0.650 |
| FEMALE | -0.516 |
| Unstandardized canonical discriminant functions evaluated at group means | |

***CLASSIFICATION FUNCTION COEFFICIENTS***

Once the discriminant functions are determined groups are differentiated, the utility of these functions can be examined via their ability to correctly classify each data point to their a priori groups. Again in Table 11, classification function coefficients also known as linear discriminant functions were presented. Classification functions derived from the linear discriminant functions are used to achieve this purpose. This is expressed as *C*k= *C*k0 + *C*k1x1 + *C*k2 x 2 +...+ *C*km*X*m. Where *C*kis the classification score for group k and *C* is the Coefficient. These coefficients are presented for each parameter according to sex.

**TABLE 11- Classification function coefficients of combined shoe print dimensions**

|  |  |  |
| --- | --- | --- |
|  | SEX | |
| MALE | FEMALE |
| RSL | 5.45 | 5.31 |
| RSB | 4.35 | 3.85 |
| LSL | 4.39 | 4.20 |
| LSB | 3.85 | 3.54 |
| (Constant) | -161.55 | -146.12 |
| Fisher's linear discriminant functions | | |

**MALE GENDER LINEAR DISCRIMINAT FUNCTION**

5.45 (RSL) + 4.35 (RSB) + 4.39 (LSL) + 3.85 (LSB) -161.552

**FEMALE GENDER LINEAR DISCRIMINAT FUNCTION**

5.31 (RSL) + 3.85 (RSB) + 4.20 (LSL) + 3.54 (LSB) -146.126

**TABLE 12- Classification function coefficients of right shoe print dimensions**

|  |  |  |
| --- | --- | --- |
| **Classification Function Coefficients** | | |
|  | SEX | |
| MALE | FEMALE |
| RSL | 8.72 | 8.44 |
| RSB | 8.27 | 7.49 |
| (Constant) | -147.87 | -133.82 |
| Fisher's linear discriminant functions | | |

**MALE GENDER LINEAR DISCRIMINAT FUNCTION**

8.72 (RSL) + 8.27 (RSB) -147.87

**FEMALE GENDER LINEAR DISCRIMINAT FUNCTION**

8.44 (RSL) + 7.49 (RSB) -133.82

**TABLE 13- Classification function coefficients of left shoe print dimensions**

|  |  |  |
| --- | --- | --- |
| **Classification Function Coefficients** | | |
|  | SEX | |
| MALE | FEMALE |
| LSL | 8.55 | 8.18 |
| LSB | 7.36 | 6.82 |
| (Constant) | -141.76 | -127.83 |

**MALE GENDER LINEAR DISCRIMINAT FUNCTION**

8.55 (LSL) + 7.36 (LSB) -141.76

**FEMALE GENDER LINEAR DISCRIMINAT FUNCTION**

8.18 (LSL) + 6.82 (LSB) -127.83

**TABLE 14- Classification function coefficients of combined footprint dimensions**

|  |  |  |
| --- | --- | --- |
|  | | |
| **She and foot dimensions** | SEX | |
| MALE | FEMALE |
| RTI | 0.03 | 0.04 |
| RT2 | 2.67 | 2.46 |
| RT3 | -7.94 | -7.28 |
| RT4 | 9.60 | 8.92 |
| RT5 | 3.45 | 3.58 |
| RBAB | 0.00 | 0.02 |
| RBAH | -0.46 | -0.49 |
| LT1 | 9.29 | 8.98 |
| LT2 | 0.10 | 0.10 |
| LT3 | -0.65 | -0.97 |
| LT4 | -5.63 | -5.23 |
| LT5 | 3.70 | 3.38 |
| LBAB | 10.62 | 10.33 |
| LBAH | 0.09 | 0.04 |
| **(Constant)** | -214.07 | -196.45 |
| Fisher's linear discriminant functions | | |

**MALE GENDER LINEAR DISCRIMINAT FUNCTION**

0.03 (RTI) 2.67 (RT2) -7.94 (RT3) + 9.60 (RT4) + 3.45 (RT5) + 0.00 (RBAB) -0.46 (RBAH) + 9.29 (LTI) + 0.10 (LT2) -0.65 + (LT3) -5.63 (LT4) 3.70 (LT5) 10.62 (LBAB) + 0.09 (LBAH)-214.07

**FEMALE GENDER LINEAR DISCRIMINAT FUNCTION**

0.04 (RTI) + 2.46 (RT2) -7.28 (RT3) + 8.92 (RT4) + 3.58 (RT5) + 0.02 (RBAB) -0.49 (RBAH) + 8.98 (LTI) + 0.10 (LT2) -0.97 (LT3) -5.23 (LT4) + 3.38 (LT5) + 10.33 (LBAB) + 0.04 (LBAH)-196.45

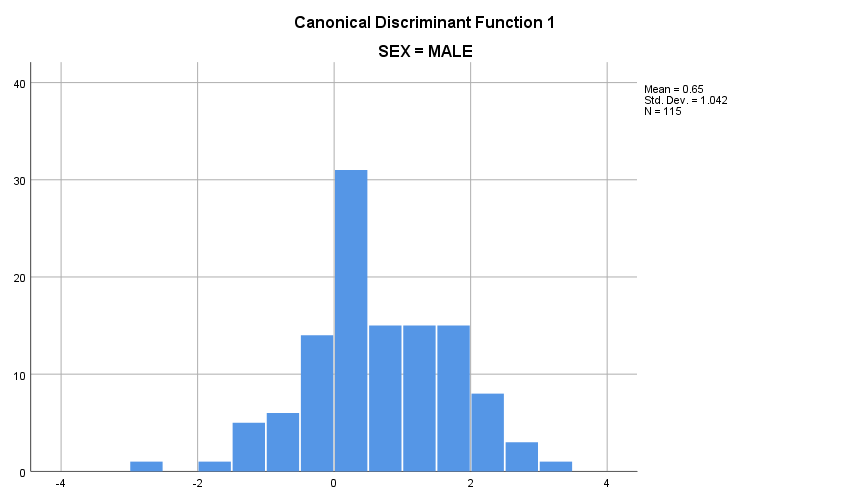
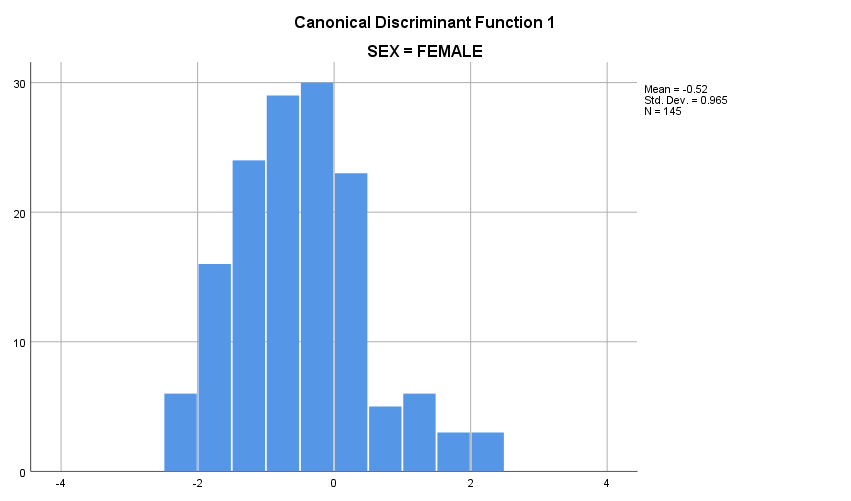


Figure 1: present Histogram showing skewness of canonical discriminant function with a cluster of male determined sex tilting to the right and female tilting to the left.



**Figure 2**: Present Histogram showing skewness of canonical discriminant function with a cluster of male determined sex tilting to the right and female tilting to the left.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Table 15-Present the results of Classification Summary of variables** | | | | | |
| Prediction (%) |  | SEX | Predicted Group Membership | | Total |
|  |  | MALE | FEMALE |
| Original | Count | MALE | 92 | 33 | 115 |
| FEMALE | 32 | 113 | 145 |
| % | MALE | 73.9 | 26.1 | 100.0 |
| FEMALE | 25.5 | 74.5 | 100.0 |
| Cross-validatedb | Count | MALE | 90 | 35 | 115 |
| FEMALE | 42 | 103 | 145 |
| % | MALE | 65.2 | 34.8 | 100.0 |
| FEMALE | 29.0 | 71.0 | 100.0 |
| a. 84.2% of original grouped cases correctly classified. | | | | | |
| c. 78.6% of cross-validated grouped cases correctly classified. | | | | | |

**RESULT SUMMARY**

LT1 (0.721), LT3 (0.692), RSB (0.684), LT4 (0.656), RT2 (0.643), RT4 (0.626), LT5 (0.626) are the variables with the highest prediction strength for group membership classification, with the least being R5DPL (-0.020). According to the classification summary 84.2% of the foot parameters measured were ab initio correctly classified according to sex; however, upon cross validation, 76.8% of the grouped cases therefore accurately classified.

**DISCUSSION**

The Discriminant function Equations derived from this study population to predict sex amongst adults of Cross River population cannot be used for another tribe because this parameters are ethnic specific.

The results of the present study in Tables- 1, 2 and 3 shows the outcome of descriptive statistics for the males, females and total combined sample respectively. This results recorded statistical significant differences (P<0.05) in the studied shoe and footprints dimensions with consistent higher values in the males when compared with their female counterparts (table 5).

The outcome of paired sample t-test for bilateral asymmetry between the left and right footprint dimensionsin the combined sample which showed statistical significant difference (P<0.05) in almost all the footprint dimension but except three (T3, T4 and T5). Which shows that the left foot is not same with the left wwith consistent higher vales recorded in the right foot.

Table 5-shows results of Independent sample t-test for sexual dimorphism for measured left and right footprints dimensions with RT2,RT3,RT4,RT5,RSL and RSB parameters shows statistical significant difference (P<0.05) for the right shoe and footprints dimensions. However, all parameters of the left shoe and footprints recorded P<0.05 except for LT1 and LBAH parameters did not show mean differences between the males and females

The present result from tables 6-15 as well as figure 1 and 2 showed different Discriminant function analysis (DFA) for sex determination using all eighteen(18) parameters,variable with Wik’s Lambda values having P<0.001 are good predictors of sex, indicating that prediction using this measured variables has a confidence interval of prediction of about 99.999% (Table 6).

Table 7- presents the result of Tests of equality in population covariance matrices and canonical correlation of (0.803)2, which is converted to percentage and suggests that the model can only explain 64.48% of the grouping (discriminating) variables (i.e. the sex of the individual).

Table 8- present Wilks' lambda test for predictability into group membership showed that the predictor variables will make statistically significant predictions where Wilk’s lambda = 0.747 and ***p*** value is less than 0.001 thus showing 99.999% confidence level.Table 9- shows results of Canonical discriminant function coefficient structured, standardized and unstandardized .Variables with asterisk represents hierarchy of predictability strenght; \*\*\*strong predictions; \*\*average prediction; \*poor prediction. where LT1,LT3,LT4,RSB,RT2,RT4,LT5,RT3,RT5,RSL and LSB parameters shows strong predictions of sex And LSL,LBAB,LBAH and RBAH parameters showing average predictions of sex using shoe and footprint dimensions with RBAB,RTI and LT2 parameters showing poor prediction strength.

Table 10- Shows the group centroids (the group mean of the predictor variables), is a function of group membership or classification and also serves as a classification cut off thus a medium of discrimination. The males have a group mean of 0.650, while the females have a group mean of -0.516. Hence functions at group centroids with a group mean near to a centroid is predicted to belong to that group (i.e. close to 0.650 as male, while -0.516 as female).Table 11- present classification function coefficient classification function coefficients also known as linear discriminant functions were presented. Classification functions derived from the linear discriminant functions are used to achieve this purpose which is expressed as *C*k= *C*k0 + *C*k1x1 + *C*k2 x 2 +...+ *C*km*X*m. Where *C*kis the classification score for group k and *C* is the Coefficient. These coefficients are presented for each parameter according to sex. Table 11- Shows for both male and female gender linear discriminant functionwith various constants of -161.55 in male and -146.12 in female respectively for shoe print parameters. Whereas classification functions of both male and female gender linear discriminant function showed constants of -214.07 in male and -196.45 female respectively for all the foot print parameters

TABLE 12. Table 13- showed for only right shoe parameters gender linear discriminant functions with relative constants of -147.87 male and -133.82 female respectively.

Table 14- Shows for only left shoe print parameters gender linear discriminant functions with constants of -141.76 male and -127.83 female respectively.

Figure 1: present Histogram showing skewness of canonical discriminant function with a cluster of male determined sex tilting to the right and female tilting to the left. Figure 2: present Histogram showing skewness of canonical discriminant function with a cluster of male determined sex tilting to the right and female tilting to the left.

The equation and centroids cut offs gotten from this study differs from the results of Hemy *et al[12]* on western Australians and that of Atamturk *et al[16]* amongst the Turks derived discriminant function cut offs and prediction accuracy percentages ranging between 79.5%-89.5% and 66.7%-82.4% respectively for sex determination using footprints dimensions. Also Fawzy *et al[23]* which indicated that even if all footprints dimensions were jointly used, a perfect (i.e 100%) accuracy of sex determination would be unattainable which is similar to the observation from the current study but their male and female discriminant factors derived differs from the values of this study.

**CONCLUSION**

The utility and reliability of sex determination standards developed from shoe and footprints dimensions amongst adults of Cross River State are of great significance in forensic practice. The current study have shown that the accuracy of shoe and footprint dimensions in sex determination is relatively high. The recorded foot index measurement is higher in the males compared to the females. This difference in group function centroids cut offs between the males and females showed gender differences in footwear and footprint dimensions. Even though this results cannot be applied in every world populations, it is recommended that other works be conducted in other world population.

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