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Sex Determination Using Discriminant Function Analysis of Handprint Variables Amongst Adults of Cross River State, Nigeria.

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ABSTRACT
Forensic investigation is very crucial towards attaining a crime free society and identification of humans in disaster related issues. This aimed at determining sex from handprints dimensions. The handprint were taken from 232 subjects (102 males and 130 females) aged between 18-45 years, whose parents are of Cross River State, void of congenital or acquired handprint deformities. Handprint collection was taken by smearing indelible ink on a constructed ink pad and the hand of the participant was placed gently against the inkpad and then place with a little pressure on the A4 sized white paper to make outline of handprint the paper was allowed to dry after which anatomical landmarks were drawn using HB pencil followed by measurement using a meter rule calibrated in centimeters. This data was analysed using SPPSS software version 21 Chicago incorporated. Result of independent sample t-test for sexual dimorphism for measured left hand and right hand prints dimensions of male and female of Cross River State are statistically significant different ($P<0.05$). This data reveals that male and female values are sexually dimorphic ($P<0.05$) in right and left total hand print dimensions measured, as greater values are consistently observed in the males than females. The result of discriminant function test record 1.267 and -0.994 as male and female cut off of group centroids function of prediction differs. This variation in function group centroids value shows that handprints can predict sex accurately. More so the hand print dimension of male is significantly higher ($p<0.05$) than female. Therefore, data from this research will be of great importance in forensic practice in aspect of human identification by engaging handprint dimension associated with sex differentiation in human individualization.

Key Words: Forensic Science, Discriminant Function Analysis, Handprints Dimensions

INTRODUCTION
The emergence of forensic science to deal with identification of human remains with the help of metric techniques has reduced the complexities that exist in forensic investigation responsibilities arising from crimes, natural and man-made disasters[1&2] Dismembered body parts are frequently found in recent times, due to increased events of natural disasters like earthquake, landslide etc. and man-made disasters like stampedes, building collapse, road traffic, air and railway accidents, mining accidents, fire, explosions etc.[3] Also in crimes like assassination, mutilation of dead body is done by a murderer to destroy all traces of identity as well as to facilitate the disposal of the dead.[3] Forensic scientists' plays a major role in providing a tentative identification of unknown remains by formulating a 'biological profile' of the victim by employing the big fours (of stature, sex, age and ethnicity) which involves the determination.[4&5] Among this 'big fours' of the biological profile, determination of sex is considered as one of the main parameter of personal identification in forensic examinations.[4] Palm and fingerprints are viewed as one of the best methods of absolute identification of a person as they are exceptional, unique and perpetual by nature.

Palm print is a mix of two parts, the palmar friction ridges and the palmar flexion creases and palmar friction ridges are the corrugated skin patterns with sweat glands yet no hair or oil glands.[6&7] Discontinuities in the epidermal ridge patterns are known as the palmar flexion creases. Flexion wrinkles (creases) appear before the arrangement of friction ridges during the embryonic skin development stage, and both elements are guaranteed to be changeless, lasting and unique to an individual.[1]

On touching or grasping an object, a trace of the friction ridge skin may be found, based on the fact that, the hypothernia area comes in contact with the supporting surface while writing, drawing or signing, an impression of part of the hand and/ or the palm can be found.[8

Since sweat is apparently a colourless fluid, the prints so left behind are not visible (latent) to the naked eyes, the visibility of the prints are enhanced by various chemical methods and reagents including ink and magnetic powder. Analysis of finger and palm prints at the crime scene is vital to identify the suspect and establish a crime.[9]

The rule of handprint in forensic science as it concern human identification cannot be over emphasized, because often than not, assassination occur and sometimes the assailants chose to strangle the victims and handprints are commonly seen on door handles, walls, guns and any other place that came in contact with the perpetrator left in a crime scene can help the forensic investigator to link the suspect with the crime by predicting stature and sex using inexpensive methods.[4&5] In developing countries like Nigeria and particularly Cross River State where this study was carried out, gender determination using handprint parameters among adult has received no attention and there is dearth of data despite the significance in human identification.

MATERIAL AND METHODS

Ethical Approval: The ethics and health research committee of the faculty of Basic Medical Sciences, Cross River University of Technology, Nigeria approved the commencement of this research. The lead researcher was communicated to granting the progress of this research.

Materials: The materials, which are used for this study include: Ink pad for obtaining the outline of the Handprints, removable ink for colour contrast patent print on the white paper, meter rule for measurement of the length and breadth of the Handprint dimensions, A4 plain paper to bear the outline of the prints, HB Pencil and pen to draw the measured landmarks, detergent and water to remove ink from the participants hands and hand towel to clean water.

Handprints acquisition method: The removable endorsing ink was poured on a constructed ink pad, then participants were asked to gently place against the inkpad and impress it with little pressure against the already pinned A4 sized white plane paper to make the handprint outline. The paper was allow to dry after which anatomical landmarks were highlighted and drawn using HB pencil followed by measurement using a meter rule calibrated in centimetres. All the measurement protocols were taken in line with the works of Nandi *et al*[4]

Handprint Length (HPL): The handprint length (HPL) was measured as straight distance between the midpoint of the distal crease of wrist joint and the most anterior projecting point i.e. tip of middle finger.Haven marked the mid-stylion crease and the tip of the middle finger from the hand impression on the white paper, a line was drawn using pencil joining the two landmarks and readings were taken using meter rule in cm.

Handprint Breadth (HPB): The measurement of HPB was taken as the distance from the most laterally projected part of the palm print at the 2nd metacarpal to the most medially projected part of the palm print at the distal transverse crease with the use of a pencil and meter rule, a line was drawn from the 2nd metacarpal (metacarpomediale) to the 4th metacarpal (metacarpolaterale)

Print digits length: The various digit lengths (Index (DL2); Middle (DL3); Ring (DL4) and Little Finger (DL5), was measured as the distance between the proximal flexion creases of the finger to the tip (dactylion) of the respective fingers. The Thumb (T1) was not measured because the landmarks of most prints were not clearly seen.

Protocol: The anatomical landmarks were marked and a straight line drawn from the proximal flexion crease to the tip (dactylion) of the respective fingers, with the use of a meter rule readings were taken to the nearest 0.01cm.

Statistical Analysis: The data acquired were subjected to series of analyzed using Statistical Package for Social Sciences (SPSS) software version 21, 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.

Figure 1: Measurement protocol of different handprint dimensions of the left hand.

RESULTS

The present result was analysed using statistical package for social sciences 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- The results descriptive statistics for right hand dimensions of the males and females

SEX		RHPL	RHPB	RPPL	R2DPL	R3DPL	R4DPL	R5DPL
	Mean±SD	19.09±0.9^{D}	8.22±0.4^{G}	10.60±0.5^{T}	7.33±0.4^{C}	8.42±0.5^{H}	7.74±0.5^{L}	6.00±0.4^{S}
	S.E	0.097	0.042	0.056	0.049	0.049	0.049	0.049
	Min	16.20	7.30	9.50	6.00	7.00	6.30	4.60
	Max	21.60	9.20	12.20	8.30	9.40	8.80	7.30
Female	Mean±SD	17.38±1.0^{D}	7.32±0.4^{G}	9.70±0.5^{T}	6.76±0.5^{C}	7.68±0.5^{H}	7.04±0.5^{L}	5.48±0.4^{S}
	S.E	0.088	0.037	0.050	0.044	0.050	0.047	0.0423
	Min	15.00	6.20	8.30	5.50	6.20	5.60	4.30
	Max	20.80	9.00	11.30	8.30	9.10	8.50	6.60
Total	Mean±SD	18.13±1.3	7.71±0.6	10.10±0.7	7.01±0.5	8.01±0.6	7.35±0.6	5.71±0.5
	S.E	0.085	0.040	0.048	0.039	0.042	0.041	0.036
	Min	15.00	6.20	8.30	5.50	6.20	5.60	4.30
	Max	21.60	9.20	12.20	8.30	9.40	8.80	7.30

Values with similar superscripts are statistical significant different between the males and females at P<0.001
Key: S.E = Standard Error, SD = Standard Deviation, RHPL = Right handprint Length, RHPB = Right handprint Breadth, RPPL = Right Palmprint Length, R2DPL = Right two digit print length, R3DPL = Right three digit Print length, R4DPL = Right Four digit print length

Table 2- The results descriptive statistics for Left hand dimensions of the males and females

SEX		LHPL	LHPB	LPPL	L2DPL	L3DPL	L4DPL	L5DPL
Male	Mean±SD	18.89±0.9^{A}	8.08±0.9^{B}	10.54±0.5^{C}	7.18±0.5^{X}	8.29±0.5^{V}	7.57±0.5^{U}	5.87±0.5^{K}
	S.E	0.096	0.041	0.056	0.051	0.050	0.051	0.048
	Min	16.00	7.20	9.30	6.00	7.00	6.10	4.50
	Max	21.40	9.00	12.10	8.20	9.30	8.80	7.10
Female	Mean±SD	17.17±0.9^{A}	7.20±0.4^{B}	9.62±0.5^{C}	6.60±0.5^{X}	7.55±0.5^{V}	6.88±0.5^{U}	5.31±0.4^{K}
	S.E	0.087	0.037	0.052	0.045	0.048	0.047	0.041
	Min	14.80	6.00	8.00	5.40	6.00	5.30	4.30
	Max	20.60	8.80	11.20	8.00	9.00	8.30	6.40
Total	Mean±SD	17.93±1.3	7.59±0.6	10.02±0.7	6.85±0.5	7.87±0.6	7.19±0.6	5.56±0.5
	S.E	0.085	0.040	0.040	0.039	0.042	0.041	0.036
	Min	14.80	6.00	8.00	5.40	6.00	5.30	4.30
	Max	21.40	9.00	12.10	8.20	9.30	8.80	7.10

Values with similar superscripts are statistical significant different between the males and females at P<0.001
Key: S.E = Standard Error, SD = Standard Deviation, LHPL = Left handprint Length, LHPB = left handprint Breadth, LPPL = left Palmprint Length, L2DPL = Left two digit print length, L3DPL = Left three digit Print length, L4DPL = left Four digit print length

Results of Discriminant Function Test for Estimation of Sex

Table 3- The result of discriminant function analysis (DFA) for sex determination

	Wilks' Lambda	F	df1	df2	Sig.
RHPL	0.578	167.672	1	230	0.001*
RHPB	0.474	255.620	1	230	0.001*
RPPL	0.617	142.623	1	230	0.001*
R2DPL	0.758	73.366	1	230	0.001*
R3DPL	0.688	104.348	1	230	0.001*
R4DPL	0.696	100.274	1	230	0.001*
R5DPL	0.779	65.066	1	230	0.001*
LHPL	0.572	172.081	1	230	0.001*
LHPB	0.484	245.219	1	230	0.001*
LPPL	0.620	141.109	1	230	0.001*
L2DPL	0.763	71.463	1	230	0.001*
L3DPL	0.677	109.771	1	230	0.001*
L4DPL	0.703	97.048	1	230	0.001*
L5DPL	0.744	79.006	1	230	0.001*

Tests of Equality of Group Means: Discriminant function analysis (DFA) was carried out using fourteen (14) parameters. In Table 5, the test of equality of mean difference for male and female values were carried out, with all the fourteen (14) entered into the model being significant (*P*< 0.001).

Tests of Equality in Population Covariance Matrices and Canonical Correlation

Table 4- Presents the result of Tests of equality in population covariance matrices and canonical correlation

Test Results		
Box's M		198.889
F	Approx.	1.772
	df1	105
	df2	146843.757
	Sig.	0.001*

Eigenvalues				
Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	1.271[a]	100.0	100.0	0.748

According to table 4, 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 $(0.748)^2$, suggests that the model can only explain 55.95% of the grouping (discriminating) variables (i.e. the sex of the individual).

Wilks' Lambda Test for Predictability into Group Membership

Table 5- Present Wilks' lambda test for predictability into group membership

Wilks' Lambda				
Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	0.440	182.891	14	0.001*

From table 5, Wilks' lambda test for predictability into group membership as presented showed that the predictor variables will make statistically significant predictions (Wilk's lambda = 0.440, *P*< 0.001).

Canonical Discriminant Function Coefficient Structured, Standardized and Unstandardized

Table 6- 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)	Function[a]	Function	Function[b]
RHPB	0.935***	0.563	1.316
LHPB	0.916***	0.197	0.460
LHPL	0.767***	-0.811	-0.820
RHPL	0.757***	-0.063	0.842
RPPL	0.699***	-0.460	-0.808
LPPL	0.695***	0.712	1.216
L3DPL	0.613***	0.731	1.367
R3DPL	0.597**	-0.599	-1.096
R4DPL	0.586**	0.371	0.705
L4DPL	0.576**	-0.128	-0.241
L5DPL	0.520**	0.307	0.641
R2DPL	0.501**	-0.248	-0.489
L2DPL	0.494**	-0.040	-0.077
R5DPL	0.472**	-0.301	-0.615
(Constant)			-19.774

Variables with asterisk represen ts hierarchy of predictability strenght; ***strong predictions; **average prediction; *poor prediction. [a]Function - Pooled within -groups correlations between discriminating variables and standardized canonical discriminant functions;
[b]Function - Coefficients used for computing group membership value

According to table 6, 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.

How to use the above Table to Predict Sex

$DF_{(eqn.)}$ = (0.842 x RHPL) + (1.316 x RHPB) + (-0.808 x RPPL) + (-0.489 x R2DPL) + (-1.096 x R3DPL) + (0.705 x R4DPL) + (-0.615 x R5DPL) + (-0.820 x LHPL) + (0.460 x LHPB) + (1.216 x LPPL) + (-0.077 x L2DPL) + (1.367 x L3DPL) + (0.241 x L4DPL) + (0.641 x L5DPL) - 19.774.

Functions at Group Centroids

Table 7- 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	1.267
FEMALE	-0.994
Unstandardized canonical discriminant functions evaluated at group means	

From table 7, 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 1.267, while the females have a group mean of -0.994. Hence functions at group centroids with a group mean near to a centroid is predicted to belong to that group (i.e. close to 1.267 as male, while -0.994 as female).

Classification Function Coefficients

Table 8- Classification function coefficients of combined shoe print dimensions

PARAMETERS	SEX	
	MALE	FEMALE
RHPL	-3.660	-5.565
RHPB	19.559	16.582
RPPL	26.730	28.557
R2DPL	4.950	6.056
R3DPL	7.716	10.195
R4DPL	-.677	-2.273
R5DPL	8.607	9.997
LHPL	-14.548	-12.692
LHPB	7.754	6.713
LPPL	8.783	6.033
L2DPL	-3.715	-3.540
L3DPL	22.833	19.741
L4DPL	-.272	.272
L5DPL	-8.904	-10.352
(Constant)	-256.230	-211.205

Fisher's linear discriminant functions

***For this table generate the linear discriminant equation with the formula given above and put in your discussion

From table 8, once the discriminate 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 ----, 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 $C_k = C_{k0} + C_{k1}x_1 + C_{k2}x_2 + ... + C_{km}X_m$. Where $C_k$is the classification score for group k and C is the Coefficient. These coefficients are presented for each parameter according to sex

Male Gender Linear Discriminat Function

-3.66 (RPHL) + 19.55 (RPHB) + 26.73 (RPPL) + 4.95 (R2DPL) + 7.71 (R3DPL) -0.67 (R4DPL) + 8.60 (R5DPL) -14.54 (LPHL) + 7.75 (LPHB) + 8.78 (LPPL) – 3.71 (L2DPL) + 22.83 (L3DPL) -0.27 (L4DPL) -8.90 (L5DPL)

Female Gender Linear Discriminat Function

-5.56 (RPHL) + 16.58 (RPHB) + 28.55 (RPPL) + 6.05 (R2DPL) + 10.19 (R3DPL) -2.27 (R4DPL) + 9.99 (R5DPL) -12.69 (LPHL) + 6.73 (LPHB) + 6.03 (LPPL) – 3.54 (L2DPL) + 19.74 (L3DPL) -0.27 (L4DPL) -10.35 (L5DPL)

The above equations were derived to predict and discriminate sex. As seen from the values formulated from, the equations are gender-specific and with unique constants and coefficients of prediction.

Table 9: Classification Summary of the entire data showing prediction percentages between the males and females

Prediction (%)		SEX	Predicted Group Membership		Total
			MALE	FEMALE	
Original	Count	MALE	88	14	102
		FEMALE	13	117	130
	%	MALE	86.3	13.7	100.0
		FEMALE	10.0	90.0	100.0
Cross-validated[b]	Count	MALE	86	16	102
		FEMALE	16	114	130
	%	MALE	84.3	15.7	100.0
		FEMALE	12.3	87.7	100.0

a. 88.4% of original grouped cases correctly classified.

c. 86.2% of cross-validated grouped cases correctly classified.

Results Summary: RHPB (0.935), LHPB (0.916), LHPL (0.767), RHPL (0.757), RPPL (0.669), LPPL (0.695), L3DPL (0.613) are the variables with the highest prediction strength for group membership classification, with the least being R5DPL (-0.615). According to the classification summary 88.4% of the handprint parameters measured were ab initio correctly classified according to sex; however, upon cross validation, 86.2% of the grouped cases therefore accurately classified.

DISCUSSION

The focal task of every forensic scientist in medico-legal investigations is first to categorise victims or suspects into male and female followed by other routine procedures[9-10]. Handprints dimensions are the most commonly seen physical and biological forms of evidence in a crime scene. In every crime scene, personal identification are sort for, either in cases of natural disaster or man-made disaster.[11-12] There is always dire need for population-specific prediction models to be formulated for proper individualization of the people.[13] The present study has derived models that can be used to discriminate the males from their female counterparts.

The present study sought to determine sex using handprint dimensions of adult Cross River State Nigeria population. Fourteen (14) handprints dimensions (RHPL, RHPB, RPPL, R2DPL, R3DPL, R4DPL, R5DPL, LHPL, LHPB, LPPL, L2DPL, L3DPL, L4DPL, L5DPL) were analysed to determine discriminant functions formulas that can differentiate gender.

The outcome of this data showed statistical significant difference ($P<0.001$) between the males and female handprints dimensions with a consistent higher values recorded among the males compared with their female counterparts (tables 1 and 2). The results presented in table 3 shows different correlations values for Wilks Lambda correlation coefficients. The variation in the values depicts different level of gender prediction accuracy.

The result of canonical discriminant function coefficient structured standardized and unstandardized was recorded in table 4-6. Handprint variables of showed various correlation values in this order RHPB, LHPB, LHPL, RHPL, RPPL, LPPL, and L3DP. The variation across the different variables in their correlation values tells sex predictability strength of the handprint dimension. Each handprint parameter was assessed for its ability to predict sex using discriminant function analysis. Similarly, the outcome of the group centroid which shows group mean of the predictor variables is a function of group membership or classification (table 7) and also serves as a classification cut off, thus a medium of discrimination, the male cut off is 1.267, while the female value is -0.994. Therefore, function at group centroids within the range of 1.267 is more likely predicted to be a male and values ranging within -0.994 favours the female sex.

Nevertheless, all the values presented from this study when compared with the findings of Varu *et al.,*[14] on sex determination using handprint dimensions reported that handprint dimensions can be used to determine the sex of an individual but the group centroids cut off recorded between the males and females differs from the outcome of the current study.

Also, comparing the results of this study with the findings by Mahrous *et al.,*[15]work on sex determination through hand dimensions among Saudi population recorded that the average hand length, breath and index were found to be 1.3, 0.96 and 2.93cm greater in Males than Females, respectively (PLO. 05). With no significant difference between right and left hand in the same sex.

The results of Ahemad and Purkait[16] on Sex determination from hand dimensions of North and South Indians also differs from the present outcome on Nigerians.

Even the results of Abd-Elaleem *et al.,*[17] on determination of Sex and Stature from Latent Palm Prints on Egyptians showed a contrary result when compared with the present data amongst Nigerians.

To provide precise and reliable formulas for prediction of sex classification accuracies of 88.4% original values and cross-validated value of 86.2% with a confidence interval of <5% (table 9) the values recorded from this study differs from those gotten from the results of Logistic regression for sex estimation was used by Ozden *et al.,*[18] and Jowaheer & Agnihotri[19]. Even when compared to the findings of Zeybek *et al.,*[20] and Bindurani *et al.,*[21] *prediction models varies from the present results.*

The variation in the values of canonical cut off for classification correlation of group centroids function, is a reliable indication that handprint dimensions can reliably predict sex with little precision error.

CONCLUSION

This results recorded statistical significant difference ($P<0.001$) between the male and female handprints dimensions with the males consistently having higher values than their females counterparts. Moreso, the discriminant function equations formulated and group centroids function cut off reported differs in both sexes. Hence, Handprint dimensions have shown from this study that it can be a reliable useful tool in determination of sex which may be applied by a forensic scientist in criminal investigation, human identification in population related issues by linking the handprints to sex of an individual.

INFORMED CONSENT

Study subject gave oral consent prior to the commencement of data collection as many of them to be unanimous. Each subject was intimated on the aim of the study as well the possible benefits and contribution to knowledge.

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