Original Article

Determination of Gender using Discriminant Analysis of Hand Dimensions among Adult Participants

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Abstract

Background: The estimation of gender using hand dimensions is a crucial role in forensic investigation and legal sciences. **Objectives:** In this study, the mean score of hand measurements have been derived and linear discriminant analysis has been applied to predict gender from hand dimensions. An independent t-test has been employed to know discrimination between male and female. The accuracy of gender estimation has been derived and checked by ROC curve.
Material and Methods: A sample of 150 participants has been collected for the completion of this study, where 78 males and 72 females were found aged between 18 and 24 years. The breadths and lengths of left and right hands of the participants have been measured.
Results: Respondents' mean score of length and breadth of left hand were found 17.69 ± 1.30 and 7.56 ± 1.17, respectively. It was found to be significantly different in the respondents' mean scores of males and females.
Conclusions: The hand dimensions of males were higher than females. The prediction of a number of females and males were 76 and 74, respectively, and its accuracy was observed 0.87. This research can be applied for larger sample and would be helpful in predicting gender discrimination among adults through hand dimensions.
Keywords: Hand dimensions, Hand Index, Sex classification, ROC curve.

INTRODUCTION

Estimation of sex using hand dimensions is a crucial role in the field of anatomy, especially in forensic study. In the past decade, many studies related to gender estimation have been carried out such as facial parameters by Maalman *et al.*, foot dimensions by Abdelu, Krishan *et al.*, dental features by Khangura *et al.*, humeral and tibial lengths by Armah *et al.* as well as ulnar and femoral lengths. Many studies have shown the correlation of stature with body parts.[1-14]

Krishan has studied the Indian perspective of the problem of stature estimation; Rastogi *et al.*; Nagesh and Kumar; Khanapurkar and Radke, and Krishan and Sharma.[7,15-18]

Most of the studies carried out to estimate the statute problems. Estimation of gender using palm dimensions have not yet been properly covered in India, especially in NCR/Delhi region, nearby capital of India. It is very important to draw the attention of such type of study which is very beneficial to forensic departments, especially in the NCR region of India. Recently Kumar *et al.* have studied on a similar topic and predicted about stature height using hand dimensions of the respondents where a regression model was employed. Further study is required to know about gender estimation using hand dimensions because it was not covered in the above studied.[19]

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This study was undertaken to examine the sex (number of male and female) using palm dimensions, such as length of right- and left hands, breath of right and left hands as well as Index of right hand, index of left hand.

The objective was to know mean of hand dimensions of male and female of respondents, to check whether hand dimensions of male and females are significant difference, and to predict of number of males and females using linear discriminant analysis, and accuracy of model can also be checked.

Hand Dimensions Measurement

A) Hand length - measured as a straight distance between the distal crease of the wrist joint and the most anterior projecting point (the middle finger).

B) Hand breadth - measured as a straight distance from the most laterally placed point on the head of 2nd metacarpal to the most medially placed point located on the head of 5th metacarpal.

MATERIALS AND METHODS

In the present study, t-test has been applied to know the difference between hand dimensions of male and female. The chi-square test is applied to know the associations between different variables of male and female. Consequently, we applied discriminate analysis for gender estimation from hand dimensions.

Data

A sample of 150 participants has been collected for the completion of this study, where 78 males and 72 females were found aged between 18 and 24 years. The breadths and lengths of left and right hands of the participants have been measured. Detailed about the data were given in Kumar *et al.*[19]

The hand index is described as the ratio between the handbreadth and the hand length multiplied by 100.[20-22]

The distribution of the hand indices has been considered based on the standard Krogman hand indices classification which is described in a study conducted in Ghana and cited in Maalman *et al.*[23] According to Chadra *et al.*, the five classifications of the hand indices are:[22]

A) Hyperdolicholicheri [40.9]
B) Dolichocheri [41.0–43.9],
C) Mesocheri [44.0–46.9],
D) Brachycheri [47.0–49.9] and
E) Hyperbrachycheri [50.0].

Statistical Analysis

SPSS 26 version and R-software have been applied for data analysis and presentation. Student's t-test has been applied to assess sex differences in the measured variables. Discriminant analysis has been applied for sex prediction. The discriminant function for sex prediction is given as: $D = \alpha + a_1x_1 + a_2x_2 + a_3x_3 + ... + a_nx_n$ The first term a represents the constant within the equation. The b's are discriminant coefficients, and the *x*'s are the measured variables or

predictors. D is the discriminant function score. To determine sex from a specific palm dimension, the measured variable has been substituted into the appropriate formula to obtain a discriminant function score. The accuracy of the discriminant function formula was assessed by ROC curve as well as by comparing the predicted sex with the actual sex.

RESULTS

The present study's sample of cross-sectional study was conducted on 150 MBBS students selected from Noida International Institute of Medical sciences, Gautam Budh nagar, India. Uni-variate and bivariate tables have been applied to present the data.

Table 1 shows descriptive statistics of students and their hand dimensions. Mean of age, height, weight, length of the left-hand, length of the right hand, a breath of left, breath right hand, left-hand index, and right-hand index were found 19.88 years, 165.9 cm., 66.5 kg., 17.7 cm, 17.6 cm, 7.56 cm, 7.79 cm, 42.51 and 44.34, respectively, and corresponding their standard deviation were found 1.2 years, 9.48 cm, 13.1 kg, 1.3 cm, 1.56 cm, 1.17 cm, 1.17 cm, 6.30 and 6.80, respectively.

Table 2 indicates the gender-wise descriptive statistics of respondents. In case of male respondents, the average of age, height, weight, length of left hand, length of right hand, breath of left, breath right hand, left-hand index, and right-hand index were found 20 years, 172.46 cm, 72.84 kg, 18.46, 18.45, 8.23, 8.48 cm, 44.64 and 46.01, respectively, whereas corresponding statistics for female were found 19.7 years, 158.82 cm, 59.56 kg, 16.86 cm, 16.77, 6.83, 7.05 cm, 40.20 and 42.54, respectively, and their corresponding standard deviation were found 1.37 years, 6.99 cm, 11.92 kg, 1.13 cm, 1.11, 1.19, 1.10 cm, 5.84, 5.72, and 0.97 years, 6.14 cm, 10.62 kg, 0.90, 0.72, 1.45, 0.72 cm, 5.99 and 7.43 for male and female, respectively. It was observed that hand dimensions of male were found higher than hand dimensions of female.

Table 1: Descriptive Statistics of respondents and their hand dimensions

Parameter	Minimum	Maximum	Mean	Std. Deviation
Age	18.00	24.00	19.8867	1.20143
Height of students	143.50	187.00	165.9147	9.48698
Weight of students	44.00	118.00	66.4687	13.10000
Length of left hand	15.00	21.00	17.6927	1.30292
Length of right hand	7.00	21.90	17.6487	1.56706
Breadh of left hand	4.96	14.80	7.5601	1.17735
Breadth of right hand	4.89	14.80	7.7964	1.17883
Left hand index	8.9	81.8	42.512	6.3072
Right hand index	28.3	92.0	44.345	6.8055

Table 3 indicates an independent sample t-test for male and female group of respondents. It was found that means of all variables significantly differed (p <0.005) at 5% significance level, for male and female respondents except age. Levene's

Table2: Gender wise descriptive statistics

|	Gender	N	Mean	Std. Deviation	Std. Error
Age	Male	78	20.0000	1.37699	.15591
	Female	72	19.7639	.97132	.11447
Height of students	Male	78	172.4603	6.99813	.79238
	Female	72	158.8236	6.14055	.72367
Weight of students	Male	78	72.8423	11.92953	1.35075
	Female	72	59.5639	10.62183	1.25179
Length of left hand	Male	78	18.4603	1.13233	.12821
	Female	72	16.8611	.90749	.10695
Breadh of left hand	Male	78	8.2319	1.11760	.12654
	Female	72	6.8324	.72214	.08511
Length of right hand	Male	78	18.4577	1.19529	.13534
	Female	72	16.7722	1.45120	.17103
Breadth of right hand	Male	78	8.4817	1.10234	.12482
	Female	72	7.0540	.72366	.08528
Left hand index	Male	78	44.646	5.8475	.6621
	Female	72	40.201	5.9986	.7069
Right hand index	Male	78	46.010	5.7244	.6482
	Female	72	42.542	7.4374	.8765
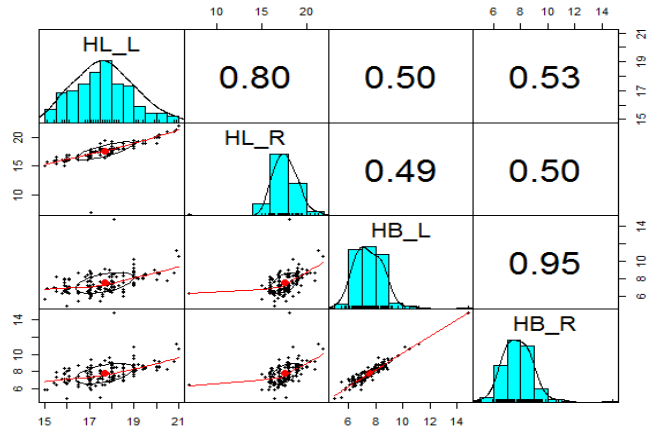
Figure 1: Scatter, correlation and histogram plots among hand dimensions of the respondents.

test for equality of variances for males and females do not differ significantly from each other (p >0.05) at 5% significance level except the respondents' age. It may be concluded that male and female hand dimensions were found significantly different. Numerically, it was observed that hand dimensions of male including hand index were higher than that of female.

Table 4 indicates the gender-wise distribution of respondents and their classifications of left-hand index. The majority of male respondents were belonged to the group 2 (41–43.9 LHI), whereas the majority of female belonged to group 1 (<40.9 LHI). It was observed from the chi-square

Table3. Independent samples test between male and female respondents

Parameter		Levene's test for equality of variances			T-test for equality of means						
	Variance	F	Sig.	T	Df	Sig. (2-Ailed)	Mean difference	Std. Error	95% Confidence	
									Lower	Upper
Age	Equal	4.765	.031	1.204	148	.230	.2361	.19605	-.15132	.6235
	Unequal			1.221	138.68	.224	.2361	.19342	-.14633	.6185
Height	Equal	.911	.342	12.641	148	.000	13.636	1.0787	11.5049	15.7683
	Unequal			12.708	147.63	.000	13.636	1.0731	11.5160	15.7572
Weight	Equal	.058	.809	7.177	148	.000	13.278	1.8502	9.6222	16.9346
	Unequal			7.210	147.81	.000	13.278	1.8416	9.6391	16.9177
Length of left hand	Equal	3.125	.079	9.494	148	.000	1.5991	.16843	1.2663	1.9319
	Unequal			9.578	145.19	.000	1.5991	.16696	1.26916	1.9291
Breadh of left hand	Equal	1.821	.179	9.027	148	.000	1.3995	.15504	1.0931	1.7059
	Unequal			9.177	132.91	.000	1.3995	.15250	1.0979	1.7012
Length of right hand	Equal	.333	.565	7.788	148	.000	1.6854	.21642	1.2578	2.1131
	Unequal			7.728	137.90	.000	1.6854	.21810	1.2542	2.1167
Breadth of right hand	Equal	1.410	.237	9.294	148	.000	1.4276	.15361	1.1240	1.7311
	Unequal			9.444	134.00	.000	1.4276	.15117	1.12865	1.72663
Left hand index	Equal	.133	.715	4.594	148	.000	4.4451	.9676	2.5330	6.3571
	Unequal			4.589	146.35	.000	4.4451	.9686	2.5309	6.3593
Right hand index	Equal	.571	.451	3.214	148	.002	3.4677	1.0790	1.3356	5.5999
	Unequal			3.181	133.16	.002	3.4677	1.0901	1.3115	5.6239

Table 4: Gender wise distribution of respondents and their classifications of left-hand index (1,2,3,4 & 5).[22]

Classification of LHI		Gender		Total	P-value
		Male	Female		
1	<40.9	15	43	58	
2	41-43.9	27	14	41	
3	44-46.9	16	8	24	χ^2= 26.4 (0.000)
4	47-49.9	10	4	14	
5	>50.0	10	3	13	
Total		78	72	150	

Table 5: Gender wise distribution of respondents and their classifications of right hand index (1,2,3,4 & 5)[22]

Classifications of RHI		Gender		Total	P-value
		Male	Female		
1	< 40.9	10	33	43	
2	41-43.9	19	17	36	
3	44-46.9	23	10	33	χ^2=22.96 (0.000)
4	47-49.9	14	8	22	
5	> 50.0	12	4	16	
Total		78	72	150	

Table 6: prediction of sex classification and its validation of the discriminant function formulas

Discrimination function formula	Sex classification accuracy (%)			Sex classification error
	Male (78)	Female (72)	Total (150)	
0.8197(HL_L)- 0.0677(HL_R)- 0.0118(HB_L)- 0.37516(HB_R)+ 0.0643(LH_I)- 0.0119(RH_I)	74	76	150 (0.84)	0.16

Figure 2: Histogram of fitted linear discriminant analysis

Figure 3: ROC Curve

ROC: The ROC curve is a popular graphic for simultaneously displaying the two types of errors for all possible thresholds. **AUC**: The overall performance, summarized over all possible thresholds, is given by the area under the ROC curve AUC. An ideal ROC curve will hug the top left corner, so the larger the AUC the better the classifier.

& *p-value* (26.44, 0.000) that there was highly significant difference between left hand Index and sex of respondents. Table 5 indicates the gender-wise distribution of respondents and their classifications of right-hand index. The majority of male respondents were belonged to group 2 (41–43.9 LHI), whereas the majority of female belonged to group 1 (<40.9 LHI). It was observed from the chi-square & *p-value* (22.96, 0.000 <0.05) that there was highly significant difference between right hand index and sex of respondents.

Figure 1 shows that scatter, correlation and histogram plots of hand dimensions. It was observed that all hand dimensions were normal. There was strong relation between breadth of left hand (HB_L) and breadth of right hand (HB_R), and very good correlation between length of left-hand (HL_L) and right hand (HL_R).

Table 6 prediction of sex classification and its validation of the discriminant function formulas. Predicted male and female numbers were found 74 and 76, respectively, whereas its total accuracy 84% has been calculated.
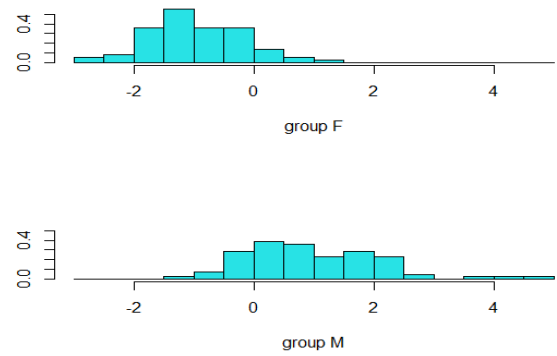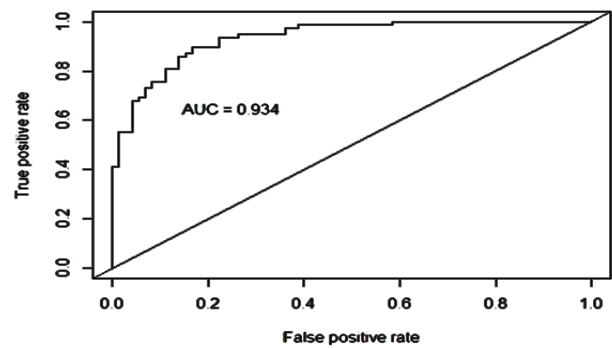
DISCUSSION

In the present paper t-test and discriminant analysis have been applied. The estimation of male and female through their hand dimensions has been calculated using discriminant analysis. The mean length of left hand, length of right hand, breath of left hand and breath of right hand were found 18.46 ± 1.13, 8.23 ± 1.11, 18.45 ± 1.19 and 8.48 ± 1.10 cm, respectively for male whereas the corresponding mean score 16.86 ± 0.90, 6.83 ± 0.72, 16.77 ± 1.45, and 7.05 ± 0.72 cm, respectively were found for female, respectively. This indicates that mean of the left hand length of male were found 1.83 higher than female, similarly, right-hand length, left hand breadth as well as right-hand breadth were found higher male than female. It is a consistent result with previous study such as Aboul-Hagag *et al.* and Agnihotri *et al.*[21,24]

Hand dimensions of male and female were found to be significantly different. Numerically, it was observed that hand dimensions of male, including hand index were higher than that of female. It was also consistent with previous studies Dey and Kapoor.[25]

As for the classification of hand index is concerned, it was observed that there was a highly significant difference between right hand index and left hand index with sex of respondents. Male and female numbers have been estimated using linear discriminant function, it was observed that male and female numbers were estimated 74 and 76, respectively, as well as it was presented as fitted graphs (Figure 2). The accuracy of predication was calculated 84.0% and presented using ROC curve (Figure 3), whereas 83.33% accuracy was calculated using Bayes model in study conducted among adult in Sri Lanka. Almost similar accuracy were found in a study, and also reported that accuracy of discriminant functions varies from 80 to 90.6%.[26,27] It can be seen in Figure 3. It is inconsistent with study carried out in Ghana, Maalman *et al.* (2021). It was found that there is very good correlation between the length of left hand and right hand as well as breath of left and right hand of the respondents.[1]

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CONCLUSIONS

In the present study, linear discriminant analysis has been applied to predict sex estimation through hand dimensions of respondents. The estimation of sex has been calculated and its accuracy has also been checked. Mean length of hand dimension of males and females have been calculated. Further t-test have been applied to know the difference of means of hand dimensions between male and female respondents. A highly significant difference was found between male and female hand dimensions. Left- and right-hand index have been calculated, and there was a significant difference between hand index and sex.

Relevance of the study

This study is enable to identify the number of gender in non-idefied situation, specially role in forensic investigation and legal sciences.

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CONFLICTS OF INTEREST

There are no conflicts of interest.

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