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SEX DETERMINATION FROM HAND, FOOT, HAND PRINT AND FOOT PRINT MEASUREMENTS OF ADULT PUNJABIS OF NORTH INDIA

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ABSTRACT

Sex determination is a very crucial aspect of forensic personal identification. The present study employs the metric method for the determination of sex in a sample of 762 individuals from Punjab State in North India. Discriminant Function analysis was used to determine sex from hand and foot measurements. Hand length, hand breadth, foot length, foot breadth, and their corresponding prints were measured. All measurements were found to be sexually dimorphic. However, hand breadth was found to be the most sexually dimorphic variable. The direct hand measurements were found to be slightly better than the print measurements. Standards for sex determination formulated in the present study can be of immense utility in forensic cases, specifically in populations of Punjab.

Key Words: Sex determination, hand length, hand breadth, foot length, foot breadth, hand prints, foot prints.

INTRODUCTION

Sex determination is considered as one of the four major parameters in forensic identification of human remains. Accurate sex determinations are critical to forensic anthropologists in establishing the identity of unknown individuals. Sex determination from skeletonized remains and human body parts is an essential component of preparation of a profile of unknown remains (Gaur, 2003). Correct sex assessment of human remains is important to narrow down the group of probable victims. Moreover, determining the sex of the unidentified remains will determine what methods are to be subsequently employed for estimating the other parameters of identification like stature and age because most of the methods used for the profiling of the unidentified are sex specific in nature(Scheuer, 2002a; Scheuer, 2002b; Cox et al., 2008).In general, males have a larger stature than females, have more robust cranial and facial features, along with greater muscularity, strength, and speed (Frayer and Wolpoff, 1985).

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There are two broad methods of estimating sex. These include the metric methods and the morphological methods or the non-metric methods.Metric methods are based on taking measurements of various dimensions of skeletal material and applying statistical analysis, usually in the form of discriminant function analysis (DFA) (Iscan, 2005). Metric methods are more easily reproducible than morphological methods because they rely on standardized osteometric points. In addition, metric methods are more objective than non-metric methods. Moreover, the simple measurements taken on the skeletal material can be transformed into indices, thus eliminating the bias in using size as a sex indicator (Arsuaga and Carretereo, 1994). Hence, these methods are more reliable and accurate and the error in assessment can further be quantified (Cox et al., 2008). One of the major limitations posed by metric methods is that the formulae derived for estimating sex from one population cannot be applied to any other population (Bruzek and Murail, 2006). In this sense, these methods are population specific.

The present study employs the metric method for the determination of sex whereby, the various measurements of the hand and feet as well as their corresponding prints have been used to compute the sectioning points using Discriminant Function Analysis. These standards will be of utmost importance in the determination of sex of unidentified individuals.

MATERIALS AND METHODS

The total sample comprised of 762 individuals from the Malwa and Doaba regions of the State of Punjab in North India. The sample was acquired using stratified random sampling method. The data were collected from the four major Districts of Punjab, namely, Bathinda, Ludhiana, Hoshiarpur, and Jalandhar. The data comprised of individuals from the four major caste groups, i.e., the Brahmins, Banias, Jat Sikhs and Khatris. Only disease free individuals without any bone deformities were selected for data collection. The data consisted of a set of anthropometric measurements of the hand and foot, which were taken following the standard protocols of Weiner and Lourie (1981) and Hall *et al.* (1989). The anthropometric measurements for each subject included the measurement of stature (cm), hand length (cm), and hand breadth (cm), as well as the foot length (cm) and the foot breadth (cm). An informed written consent was taken from the individuals prior to the sample collection.

General information like the name, age, sex, caste, address, occupation, income, educational status and marital status of each subject was also recordedin addition to the anthropometric data. Apart from the anthropometric measurements, the hand prints as well as the foot prints of both the hands and feet of the subject were obtained on a plain white cartridge sheet. The prints so acquired were then measured for the hand print length (cm),hand print breadth (cm), foot length (cm), and the foot breadth (cm)with the help of a Digital Vernier Caliper.

Technical Error of Measurement (TEM)

Before starting the final data collection, a precision test was conducted to calculate the intra-observer error (Ulijaszek and Lourie, 1994; Ulijaszek and Kerr, 1999) on a test sample of 10 individuals, who were measured consecutively for two days. In addition to that, another indicator of imprecision, namely, the Coefficient of Reliability (R) (Reynolds *et al.,* 2008) was also calculated.

The TEM values for stature, left hand length, right hand length, left hand breadth and right hand breadth were calculated to be 0.044, 0.022, 0.045, 0.067, and 0.067, respectively.

The corresponding R values were 0.862, 0.998, 0.997, 0.974, and 0.990 respectively, indicating very low values of intra-observer error; as the value of R approaches 1, the amount of variance due to measurement error decreases.The recommended values of R range from 0.75to 0.95 (Reynolds *et al.,* 2008).

Statistical Package for Social Sciences (SPSS version-18) was used to analyze the data. Descriptive statistics, Student's t-test, one-way ANOVAand Discriminant Function analysis were used for the analysis of data.

RESULTS AND DISCUSSION

Table-1 shows the mean values of hand length, hand breadth, foot length, foot breadth, handprint length, handprint breadth, foot print length, and the foot print breadth of adult Bania, Brahmin, Jat Sikh and Khatri males and females of Doaba and Malwa regions of Punjab. The table shows that the males and females of Malwa region had higher values for hand length, hand breadth as well as the foot length and the foot breadth when compared to their counterparts from the Doaba region. Similarly, for the print measurements, the males and females of Malwa region showed higher values of hand print length as well as the foot print length and breadth when compared to the males and females of the Doaba region.

Table-1: Mean values for direct and print measurements of hand and feet

			Hand measurements				Foot measurements			
Region	Caste	N	HL Mean	HPL Mean	HB Mean	HPB Mean	FL Mean	FPL Mean	FB Mean	FPB Mean
					MALES					
DOABA	Bania	47	18.63	18.38	8.29	8.05	25.62	25.41	9.94	9.69
	Brahmin	46	18.94	19.01	8.45	8.23	26.31	25.36	9.99	9.50
	Jat Sikh	50	18.76	18.90	8.51	8.25	25.77	24.58	10.03	9.32
	Khatri	49	18.48	18.47	8.19	8.18	24.95	24.95	9.76	9.76
					FEMALES					
	Bania	47	17.08	16.81	7.45	7.04	23.44	22.63	9.05	8.38
	Brahmin	50	17.19	17.04	7.55	7.22	23.30	23.04	8.94	8.61
	Jat Sikh	48	17.06	17.07	7.53	7.35	23.23	22.49	8.88	8.37
	Khatri	50	16.99	17.02	7.48	7.30	23.43	22.78	8.95	8.65
MALWA					MALES					
	Bania	48	18.85	19.05	8.44	8.43	26.01	24.82	10.05	9.37
	Brahmin	45	18.96	18.95	8.40	8.25	26.05	24.72	9.84	9.25
	Jat Sikh	46	19.19	19.38	8.62	8.57	26.47	25.01	10.18	9.40
	Khatri	40	19.01	19.16	8.42	8.37	26.14	24.88	10.02	9.30
					FEMALES					
	Bania	48	17.23	17.45	7.57	7.56	23.52	22.49	9.03	8.43
	Brahmin	49	17.42	17.30	7.61	7.46	23.63	22.34	8.98	8.44
	Jat Sikh	50	17.66	17.65	7.73	7.50	23.90	22.62	8.81	8.23
	Khatri	49	17.08	17.19	7.50	7.48	23.48	22.34	9.03	8.43

Key: HL- Hand Length, HB- Hand Breadth,HPL- Hand Print Length, HPB- Hand Print Breadth, FL- Foot

The bilateral differences (Table-2) were insignificant for all the measurements (i.e., hand length, hand print length, hand breadth, hand print breadth, foot length, foot print length, foot breadth and the foot print breadth) for both males as well as the females of Malwa and Doaba regions. But the hand breadth in females of all the caste groups showed significant bilateral differences (p<0.05). As the bilateral differences were largely insignificant (p<0.05), so only combined left and right values of various hand and foot measurements were used for further analysis.

Table- 2: Results of one-way ANOVA for bilateral differences

Measurement	BANIA		BRAHMIN		JAT SIKH		KHATRI	
	Males F Ratio	Females F Ratio	Males F Ratio	Females F Ratio	Males F Ratio	Females F Ratio	Males F Ratio	Females F Ratio
HL	0.381	0.793	0.257	0.088	0.114	0.028	0.368	0.772
HPL	0.016	0.742	0.028	0.080	0.010	0.024	0.245	0.013
HB	0.923	4.746*	0.250	7.094*	2.260	6.470*	0.348	6.317*
HPB	0.005	0.011	1.074	0.000	1.472	2.221	0.284	0.224
FL	0.166	0.573	0.270	1.186	0.431	1.178	0.330	0.272
FPL	0.165	0.605	0.335	0.808	0.033	0.189	0.106	0.171
FB	0.109	0.265	0.855	1.023	0.002	0.340	0.391	0.104
FPB	2.789	1.453	0.016	0.421	0.001	0.665	0.023	0.019

*Significant bilateral difference (p<0.05)

Key: HL- Hand Length, HB- Hand Breadth,HPL- Hand Print Length, HPB- Hand Print Breadth, FL- Foot Length, FPL- Foot Print Length, FB- Foot Breadth, FPB- Foot Print Breadth

Table-3 incorporates the results of sex differences for direct hand and foot measurements as well as their corresponding print measurements in various caste groups. Males were found to be comparatively larger than the females and statistically significant differences were observed for all the measurements. The results further revealed that the hand breadth as well as the hand print breadth was the most potent determinants of sex for all caste groups. However, the hand length and the hand print length were also good indicators of sexual dimorphism. For foot measurements, foot length and the foot print length were found to be better determinants of sex when compared to the foot breadth and the foot print breadth.

Table-3: Results of one way ANOVA to study sex differences

Measurement	Banias F Value	Brahmins F Value	Jat Sikhs F Value	Khatris F Value
HL	231.204*	149.033*	172.746*	187.381*
HB	232.924*	210.702*	271.815*	248.814*
HPL	164.629*	182.721*	163.619*	168.239*
HPB	178.832*	167.794*	256.100*	228.978*
FL	205.178*	239.434*	276.832*	119.917*
FB	133.736*	143.216*	164.647*	122.321*
FPL	232.976*	97.136*	197.609*	136.392*
FPB	139.520*	86.663*	134.446*	120.159*

*Significant sex difference (p<0.05)

Key: HL- Hand Length, HB- Hand Breadth,HPL- Hand Print Length, HPB- Hand Print Breadth, FL- FootLength, FPL- Foot Print Length, FB- Foot Breadth, FPB- Foot Print Breadth

Table-4 suggests that the caste differences were insignificant for a majority of the measurements, barring the hand breath, which showed significant caste differences (p<0.05) for both males as well as the females.

Table-4: Results of one way ANOVA to study caste differences

Measurement	Males		Females	
	F Value	Sig	F Value	Sig
HL	2.030	0.109	3.647	0.013*
HB	7.303	0.000*	3.121	0.026*
HPL	3.472	0.016*	2.034	0.109
HPB	2.626	0.050	1.462	0.224
FL	5.939	0.001*	0.234	0.873
FB	2.075	0.103	2.430	0.065
FPL	0.879	0.452	0.314	0.815
FPB	2.116	0.098	3.544	0.015

*Significant caste difference (p<0.05)

Key: HL- Hand Length, HB- Hand Breadth,HPL- Hand Print Length, HPB- Hand Print Breadth, FL- Foot Length, FPL- Foot Print Length, FB- Foot Breadth, FPB- Foot Print Breadth

Table-5 exhibits that there is no clear pattern of regional differences among the Bania, Brahmin, Jat Sikh and Khatri males and females of Punjab. Therefore, the two regions, namely, the Malwa and Doaba regions were combined for further analysis.

Table- 5: Results of one-way ANOVA to study regional differences

Measurements	Males				Females			
	Bania F ratio	Brahmin F ratio	Jat Sikh F ratio	Khatri F ratio	Bania F ratio	Brahmin F ratio	Jat Sikh F ratio	Khatri F ratio
HL	2.139	0.012	5.856*	7.930*	1.310	1.826	16.665*	0.337
HB	2.920	0.266	1.618	11.684*	3.331	0.574	7.558*	0.072
HPL	14.60*	0.06	5.19*	13.23*	18.35*	2.41	13.25*	1.07
HPB	13.86*	0.04	14.57*	6.56*	51.99*	6.42*	3.11	4.34
FL	2.897	0.919	10.077*	19.039*	0.121	2.087	12.569	0.052
FB	0.800	1.445	0.747	4.913*	0.044	0.159	0.382	0.557
FPL	6.62*	5.08*	2.64	0.06	0.35	10.45*	0.56	2.00
FPB	6.13*	3.27	0.28	13.97*	0.15	2.05	2.15	2.93

*Significant regional difference (p<0.05)

Key: HL- Hand Length, HB- Hand Breadth,HPL- Hand Print Length, HPB- Hand Print Breadth, FL- Foot Length, FPL- Foot Print Length, FB- Foot Breadth, FPB- Foot Print Breadth

As the main purpose of the present study was to determine sex of an individual from the various anthropometric measurements, a Discriminant Function Analysis was employed to compute the sectioning points for gender discrimination. Univariate (i.e., from direct single variable) equations were formulated for both direct as well as the print measurements of hand and foot.

Table-6 shows the values of raw coefficients, Wilk's Lambda, group centroids, sectioning points and the percentage accuracy for direct as well as the print measurements of the hand and the foot. Each measurement was used separately for predicting the accuracy percentages of correct sex classification.It follows from the table that the hand breadth showed the highest overall accuracy of classification (86.2%), followed by the foot print length (84.1%), foot length (83.7%), hand length (83.3%), hand print breadth (83.2%), hand print length (82.5%), foot breadth (81.6%) and the foot print breadth (80.6%). Further, if we examine the values, the lowest value of Wilk's lambda was shown by hand breadth (0.450), followed by the hand print breadth (0.485), foot length (0.489) and hand length (0.517). The closer the value of Wilk's lambda is to 0, the more the variable contributes to the discriminant function.

Table- 6: Univariate Discriminant Function Analysis showing the values of unstandardised coefficients, Wilk's Lambda, Group centroids, sectioning point and the percentage accuracy of hand and foot measurements

Variable	Unstandardised coefficient	Wilk's Lambda	Group Centroids		Sectioning point (M+F)/2	Demarking points	Correctly assigned
			Male	Female			
HLConstant	1.187-21.374	0.517	0.992	-0.941	0.0255	18.03	83.3%
HBConstant	2.561-20.418	0.450	1.133	-1.075	0.029	7.985	86.2%
HPLConstant	1.097-19.765	0.532	0.964	-0.912	0.026	18.2	82.5%
HPBConstant	2.229-17.419	0.485	1.057	-1.000	0.285	7.81	83.2%
FLConstant	0.848-20.926	0.489	1.049	-0.995	0.027	24.67	83.7%
FBConstant	1.681-15.889	0.576	0.879	-0.834	0.0225	9.45	81.6%
FPLConstant	0.767-18.197	0.554	0.921	-0.872	0.0245	23.73	84.1%
FPBConstant	1.554-13.882	0.618	0.808	-0.764	0.022	8.93	80.6%

Key: HL- Hand Length, HB- Hand Breadth,HPL- Hand Print Length, HPB- Hand Print Breadth, FL- Foot Length, FPL- Foot Print Length, FB- Foot Breadth, FPB- Foot Print Breadth

Hence, it follows that in the present sample, the hand breadth is the most discriminating of all the variables. This finding is in consonance with several studies (Agnihotri et al., 2008; Krishan et al., 2011; Ishak et al., 2012; Dey and Kapoor, 2015). The highest value of Wilk's lambda was shown by the foot print breadth (0.618), thereby making it the least discriminating variable for determining sex.

The value of sectioning point indicates the group to which the individual belongs i.e., it helps to discriminate the sex. It was calculated from group centroids by using the formula: M centroid+ F centroid/2. The individuals with the values above the sectioning point are classified as males and those below the sectioning points are the females for that particular variable.

The general discriminant equation for direct single variable is presented as: D= Constant + bX,

where D is the discriminant score, b is the unstandardised coefficient and X is the variable such as hand length, hand breadth and so on.

The overall classification accuracy for hand length was found to be 83.3% while that for the hand breadth was 86.2%. For hand print length and breadth, the overall accuracy was found to be 82.5% and 83.2%, respectively. Foot length showed a correct percent accuracy of 83.7% for direct measurements, while the foot print length showed a correct percent accuracy of 84.1%. The correct percent accuracy for the foot breadth was recorded to be 81.6%, while for the foot print breadth, it was found to be 80.6%.

The present study demonstrated that sex can be estimated from direct as well as the print measurements with comparable accuracy. However, the direct measurements were found to be better than the print measurements in estimating sex in the adult Bania, Brahmin, Jat Sikh and Khatris of Punjab. This can be of utmost importance in forensic cases where chance prints are encountered at the crime scene; hence, the print measurements can be relied upon for determination of sex in the absence of direct measurements.

CONCLUSIONS

It was found that the hand breadth was the most sexually dimorphic variable in the present sample. Hand length, foot length and the foot breadth were also found to be good determinants of sex. For print measurements, foot length, followed by the hand breadth and the hand length were the most discriminating variables.The estimation of sex was found to be comparatively more accurate from the hand and foot measurements as compared to their corresponding hand print and foot print measurements. Standards for sex determination formulated in the present study can be of immense utility in forensic cases, specifically in populations of Punjab.

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