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Hand Anthropometry For Forensic Identification And Sex Estimation In The Haryanvi Population

Dr. Kanika Chhikara[1]

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Abstract:

Hand biometry involves measuring and analysing unique physical characteristics of the hand for identification and forensic purposes. The hand's unique morphology and individual variations make it an effective biometric identifier, useful for personal identification and linking individuals to crime scenes. The shape and size of the hand, determined by genetics and developmental processes, remain consistent throughout a person's life, making them reliable and difficult to alter. However, in India, such databases are limited, and population variation can impact the accuracy of hand biometric identification. Combined with other forensic techniques, hand biometry enhances the accuracy and reliability of personal identification in investigations. This study aims to analyse the sexual dimorphism and discriminant functions for sex estimation from the hand in the adult Haryanvi population. A total of 26 hand variables (left and right side) were measured on 113 males and 102 females with the help of vernier callipers. SPSS 21.0 was used for statistical analysis. Student's T-test showed a significant difference between males and females. The statistical analysis revealed high significant differences between the sexes. Discriminant function analysis revealed a sex classification accuracy of 98.1% accuracy using 7 variables. The findings of this research demonstrate that hand variables could be used to estimate sex. It is used for forensic identification, especially in cases involving mutilated or decomposed remains from mass disasters or other incidents. The results of the present study can be used in different forensic scenarios for sex estimation as well as in clinical and anthropological settings.

Keywords: *Hand Biometry, Forensic Purposes, Sex Estimation, Sexual Dimorphism*

Authors:

1. *Assistant Professor, Department of Forensic Science, Faculty of Applied and Basic Sciences, Shree Guru Gobind Singh Tricentenary University, Gurugram, Haryana, INDIA.*

Introduction

Forensic anthropometry is the science of investigating different body dimensions and ratios of the human body for identification **(Choong *et al.*, 2023)** Utilizing metric methods, anthropologists can individualize by constructing a biological profile, including the big fours- age, sex, stature, and ethnicity for narrowing the pool of potential suspects **(Celbis and Hasan, 2006)** This becomes important in challenging cases such as mass disasters, and homicides, where identifying dismembered remains is crucial. Therefore, these anthropometric dimensions can be used to create sex and stature estimation models that are population-specific.

Hands as a tool for identification is increasingly becoming valuable for forensic identification as the dimensions and ratios provide insight into the sexual dimorphism of a population **(Gheat *et al.*, 2020)** The complex structure, comprising multiple bones, muscles, and connective tissues, provides a wealth of measurable variables, which collectively contribute to a comprehensive assessment of sexual dimorphism. It is further underscored by their application in scenarios where mutilated or partial remains are recovered. Discriminant function models can be developed to classify sex with considerable accuracy **(Soler, 2013)** Many researchers also believe that exposure to different sex hormones (testosterone and estrogen) during early embryonic development leads to finger length variations is regulated by HOX genes **(Ventura *et al.*, 2013; Morgan, 1997)**. It plays a crucial role in specifying characteristics and patterning of anatomical structures in the human body (Hafez and Shahin).

There is a lot of research being carried out internationally for stature estimation **(Aboul-Hagag *et al.*, 2011; Ibeachu et al., 2011; Jee *et al.*, 2015; Ishak *et al.*; Danborno and Elukpo, 2007; Zulkifly *et al.*, 2018 ; Uhrová *et al.*, 2012; Tang *et al.*, 2012 ; Charmode *et al.*, 2019)** but the data is substantially less for sex estimation. Furthermore, the Haryanvi population is still underexplored for estimating these models. Hence, the present study aims to address this lacuna in research by adding to the database for sex estimation from the hands of this population.

Materials And Methods:

Participants

This was a cross-sectional study conducted in Haryana, India. 215 participants (M= 113; F= 102) were randomly selected for the study within the age range of 18-50 years after taking informed consent. Haryanvi individuals were selected from schools, institutions, public spaces, and relatives. Participants with any deformity in hand, injury or disease were excluded from the study.

Procedure

The anthropometric measurements of left and right hands were taken by the researcher. On a flat horizontal surface, the palms of the participants' hands were made to face upward, and the forearms were aligned with the third digit of the hand. Fingers should be close together and extended maximally (Fig. 1). Using Weiner and Lourie's **(Weiner and Lourie, 1969)** standardized technique, the digit lengths of each participant for both hands were measured (in mm) directly using a digital vernier caliper (least count 0.01 mm). Sex, stature, and age were also recorded using a stadiometer for each participant.

Morphometric measurements

A total of 26 hand variables were measured (table 1; Fig. 1):

Table No. 1: Anthropometric variables measured for sample analysis.

Length	Breadth	Thickness	Circumference/ Spread
AL- Arm Length	TB- Thumb Breadth (sky blue line)	TT- Thumb Thickness (red line)	Max Spread- Maximum Spread (pink line)
HL- Hand Length (green line)	IFB- Index Finger Breadth (sky blue line)	IFT- Index Finger Thickness (grey line)	Max FS- Maximum Functional Spread (lavender line)
PL- Palm Length (orange line)	MFB- Middle Finger Breadth	MFT- Middle Finger Thickness	Wrist CF- Wrist Circumference (black line)
TL- Thumb Length (dark yellow line)	RFB- Ring Finger Breadth	RFT- Ring Finger Thickness	Wrist B- Wrist Breadth (red line)
IFL- Index Finger Length (yellow line)	LFB- Little Finger Breadth	LFT- Little Finger Thickness	
MFL- Middle Finger Length (light grey line)	HB Meta C- Hand Breadth Meta Carpal (blue line)	HT Meta C- Hand Thickness Meta Carpal (magenta line)	
RFL- Ring Finger Length (light green line)	HB Across T- Hand Breath Across Thumb (purple line)	HT Including T- Hand Thickness Including Thumb (black line)	
LFL- Little Finger Length (green line)			

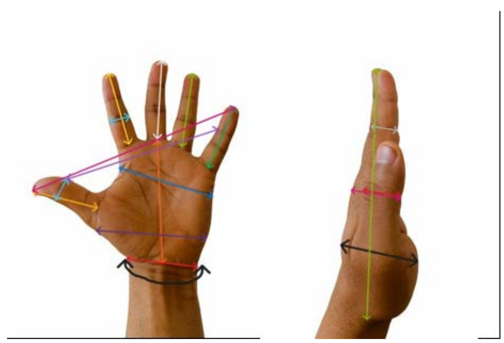

Figure No. 1: Showing different variables measured in a sample.

Statistical analysis

To analyze the collected data, SPSS 21.00 was used. The normality of the data was checked by the Shapiro-Wilk normality test at $p < 0.05$. A descriptive analysis and student's t-test on mean values were done to find significant difference levels ($p<0.05$) between the sexes. Direct and Stepwise discriminant function analysis was done for sex prediction accuracies.

To study population variation, z-scores were calculated. It refers to the anthropometric values as a number of standard deviations below or above the mean **(Wang and Chen, 2012)** It can be calculated using the formula as described in table 2.

Table No. 2: Different ways to calculate the Z score.

When we have raw score of both the reference and study population	When we know mean, SD and sample size of study population; and mean, SD of reference population (sample size unknown)	When we know mean, SD and sample size of study population; and mean, SD of reference population (sample size unknown)
• Z- score = $\frac{x-\mu}{\sigma}$ • x=observed value/raw score • μ=mean of the reference population • σ=standard deviation of reference population	• Z- score = $\frac{\bar{x}-\mu}{\frac{\sigma}{\sqrt{N}}}$ • $\bar{x}$ = *sample mean* • μ=mean of the reference population • σ=standard deviation of reference population • N= sample size of sample population	• Z- score = $\frac{\bar{x}_1-\bar{x}_2}{\sqrt{\frac{\sigma_1^2}{N_1}+\frac{\sigma_2^2}{N_2}}}$ • $\bar{x}_1$, $\bar{x}_2$ = sample mean, mean of the reference population respectively • σ_1, σ_2 = the standard deviation of sample population and reference population respectively • N_1, N_2 = sample size of sample population and reference population respectively

A positive z score signifies that the data point is above the mean and a negative z score signifies that it is below the mean.

Result:

Descriptive analysis:

Table 1 contains descriptive statistics of hand measurements of both sexes including student's t-test, demarking points and index of sexual dimorphism. It reveals highly significant differences between males and females in all hand variables ($p < 0.001$) with all males having larger measurements than females.

Demarking point is the average of mean male and mean female values for a variable. If the measurement of a variable is higher than the demarking point, it is considered male; and female if the value lies lower or equal to the point. It can be used when a deformed hand or mutilated body is obtained for sex estimation.

The Sexual Dimorphism Index (SDI) is calculated by: Male mean value*100/ Female mean value. It suggests the percentage of difference that is present between the sexes. A low degree of dimorphism is exhibited by values closer to 100 and as the value increases, the degree of dimorphism also increases **(Chhikara et al., 2023).**

Table No. 3: Descriptive statistics and sexual dimorphism in hand variables of Haryanvi population.

Variable	Male (N= 113) Mean±SD (mm)	Female (N= 102) Mean±SD (mm)	t-value	p-value	Demarking Points	Index of Sexual Dimor-phism
Left						
AL	860.96±47.69	785.85±38.1	12.81	.000	F≤823.40< M	109.56
HL	194.54±9.17	177.6±9.27	13.44	.000	F≤186.07< M	109.54
PL	109.59±5.43	99.91±5.32	13.19	.000	F≤104.75< M	109.69
TL	65.91±4.31	58.97±4.41	11.64	.000	F≤62.44< M	111.77
IFL	74.38±4.4	68.48±3.39	11.05	.000	F≤71.43< M	108.61
MFL	82.11±4.74	75.32±4.01	11.36	.000	F≤78.71< M	109.01
RFL	76.14±4.65	70.22±4.1	9.91	.000	F≤73.18< M	108.43
LFL	61.53±4.2	56.53±3.21	9.86	.000	F≤59.03< M	108.84
TB	22.07±1.4	19.6±1.32	13.24	.000	F≤20.83< M	112.60
IFB	20.32±1.12	18.07±1.04	15.10	.000	F≤19.19< M	112.45
MFB	20.32±1.11	17.96±1.15	15.23	.000	F≤19.14< M	113.14
RFB	19.25±1.22	16.86±1.08	15.20	.000	F≤18.05< M	114.17
LFB	17.52±1.1	15.46±1.09	13.76	.000	F≤16.49< M	113.32
TT	18.81±1.37	16.84±1.17	11.33	.000	F≤17.82< M	111.70
IFT	17.76±1.19	16.01±0.87	12.27	.000	F≤16.88< M	110.93
MFT	18.32±1.2	16.46±1.06	12.04	.000	F≤17.39< M	111.30
RFT	17.49±1.22	15.74±1.38	9.80	.000	F≤16.61< M	111.12
LFT	15.91±1.18	14.22±1.18	10.44	.000	F≤15.06< M	111.89
HBMETAC	92.36±4.3	81.39±3.72	20.02	.000	F≤86.87< M	113.48
HBACROSST	102.73±5.28	90.94±4.19	18.19	.000	F≤96.83< M	112.96
HTMETAC	28.38±2.01	25.56±1.74	10.98	.000	F≤26.97< M	111.03
HTINCLUDINGT	44.55±4.67	38.99±3.72	9.71	.000	F≤41.77< M	114.26
MAXSPREAD	214.01±23.96	192.37±12.26	8.45	.000	F≤203.19< M	111.25
MAXFS	154.44±13.36	139.34±10.86	9.12	.000	F≤146.89< M	110.84
WRISTCF	175±9.27	155.86±9.19	15.17	.000	F≤165.43< M	112.28
WRISTB	62.55±3.6	55.79±3.24	14.46	.000	F≤59.17< M	112.12
Right						
AL	862.46±47.58	791.02±40.02	11.95	.000	F≤826.74< M	109.03
HL	194.4±9.01	177.59±8.27	14.27	.000	F≤185.99< M	109.47
PL	108.74±5.6	99.12±5.6	12.57	.000	F≤103.93< M	109.70
TL	65.7±4.44	59.14±3.87	11.58	.000	F≤62.42< M	111.09
IFL	73.93±4.34	67.95±3.47	11.20	.000	F≤70.94< M	108.80
MFL	81.52±4.51	74.54±3.55	12.67	.000	F≤78.03< M	109.36
RFL	75.86±4.26	69.82±4.07	10.61	.000	F≤72.84< M	108.65
LFL	61.1±4.41	56.05±3.22	9.64	.000	F≤58.57< M	109.01
TB	22.43±1.47	19.95±1.33	12.95	.000	F≤21.19< M	112.43
IFB	20.6±1.16	18.54±1.26	12.39	.000	F≤19.57< M	111.11
MFB	20.69±1.16	18.39±1.08	14.97	.000	F≤19.54< M	112.51
RFB	19.62±1.09	17.38±1.31	14.71	.000	F≤18.50< M	112.89
LFB	17.78±1.18	15.59±1.26	13.09	.000	F≤16.68< M	114.05
TT	19.34±1.43	17.5±1.2	10.22	.000	F≤18.42< M	110.51
IFT	18.48±1.14	16.81±1.11	10.83	.000	F≤17.64< M	109.93
MFT	18.73±1.32	17.06±1.17	9.78	.000	F≤17.89< M	109.79
RFT	17.83±1.3	16.42±1.35	7.74	.000	F≤17.12< M	108.59
LFT	16.41±1.25	14.9±1.16	9.10	.000	F≤15.65< M	110.13
HBMETAC	92.9±4.43	82.13±4.38	17.88	.000	F≤87.51< M	113.11
HBACROSST	102.87±4.74	90.91±4.17	19.66	.000	F≤96.89< M	113.15
HTMETAC	29.13±2.11	26.13±1.88	11.04	.000	F≤27.63< M	111.48
HTINCLUDINGT	44.47±4.19	40±4.03	7.96	.000	F≤42.23< M	111.17
MAXSPREAD	211.16±16.36	187.46±11.96	12.20	.000	F≤199.31< M	112.64
MAXFS	152.39±12.6	136.1±11.29	9.99	.000	F≤144.24< M	111.97
WRISTCF	174.2±8.39	155.44±9.16	15.61	.000	F≤164.82< M	112.07
WRISTB	62.42±3.21	55.86±3.17	15.05	.000	F≤59.14< M	111.74
STATURE#	170.18±74.74	156.52±64.69	14.26	.000	F≤ 170.2< M	108.73

#in cm; AL- Arm Length; HL- Hand Length; PL- Palm Length; TL- Thumb Length; IFL- Index Finger Length; MFL- Middle Finger Length; RFL- Ring Finger Length; - LFL- Little Finger Length; TB- Thumb Breadth; IFB- Index Finger Breadth; MFB- Middle Finger Breadth; RFB- Ring Finger Breadth; LFB- Little Finger Breadth; TT- Thumb Thickness; IFT- Index Finger Thickness; MFT- Middle Finger Thickness; RFT- Ring Finger Thickness; LFT- Little

Finger Thickness; HB Meta C- Hand Breath Meta Carpal; HB Across T- Hand Breath Across Thumb; HT Meta C- Hand Thickness Meta Carpal; HT Including T- Hand Thickness Including Thumb; Max Spread- Maximum Spread; Max FS- Maximum Functional Spread; Wrist CF- Wrist Circumference; Wrist B- Wrist Breadth

Discriminant Function Analysis:

Determination of sex was carried out using discriminant function analysis using each variable for direct analysis (Table 2). The percentage accuracy for sex estimation ranged from 70.2% to 93%. For males, the highest sexing accuracy was shown by the variables HBMETAC (L) (93.8%) and WRISTCF (R) (91.2%). Whereas for females, HBACROSST (L=96.1%; R=93.1%) showed the highest sexing accuracy. Overall HBACROSST (L) had the highest accuracy for sex determination.

Table No. 4: Percentage of correct classifications for the discriminant functions of different hand variables for the left and right hand.

Variables	LEFT			RIGHT		
	Male %	Female %	Average accuracy %	Male %	Female %	Average accuracy %
AL	83.2	83.3	83.3	82.3	84.3	83.3
HL	83.2	86.3	84.7	83.2	83.3	83.3
PL	77.9	84.3	80.9	81.4	81.4	81.4
TL	77.9	79.4	78.6	78.8	80.4	79.5
IFL	76.1	83.3	79.5	71.7	77.5	74.4
MFL	80.5	77.5	79.1	77.9	79.4	78.6
RFL	63.7	77.5	70.2	73.5	79.4	76.3
LFL	70.8	80.4	75.3	73.5	77.5	75.3
TB	80.5	81.4	80.9	78.8	82.4	80.5
IFB	82.3	84.3	83.3	79.6	75.5	77.7
MFB	84.1	86.3	85.1	84.1	88.2	86.0
RFB	84.1	86.3	85.1	83.2	87.3	85.1
LFB	80.5	81.4	80.9	83.2	82.4	82.8
TT	78.8	84.3	81.4	74.3	74.5	74.4
IFT	74.3	85.3	79.5	71.7	73.5	72.6
MFT	74.3	79.4	76.7	67.3	78.4	72.6
RFT	78.8	71.6	75.3	71.7	69.6	70.7
LFT	79.6	79.4	79.5	69.9	75.5	72.6
HBMETAC	93.8	91.2	92.6	89.4	90.2	89.8
HBACROSST	90.3	96.1	93	86.7	93.1	89.8
HTMETAC	77.0	78.4	77.7	77.0	73.5	75.3
HTINCLUDINGT	68.1	72.5	70.2	68.1	69.6	68.8
MAXSPREAD	86.7	68.6	78.1	83.2	81.4	82.3
MAXFS	68.1	74.5	71.2	73.5	81.4	77.2
WRISTCF	81.4	89.2	85.1	91.2	79.4	85.6
WRISTB	82.3	85.3	83.7	86.7	85.3	86.0

The standardized and unstandardized discriminant function coefficients, structure matrix, sectioning points and average accuracy of original samples is given in table 3. The discriminant scores can be calculated using the raw coefficients for all the functions. Each variable is multiplied by its raw coefficients, adding them and then adding the constant.

For example, for function 2, the discriminant score can be calculated as:

D = [HBACROSST(L)*0.208]

In stepwise analysis, 7 predictor variables in F1 were included, predicting original and cross-validation accuracy of 98.1%. In direct analysis, F2 included the single best variable (HBACROSST(L)), with an accuracy of O=93%; C= 92.6%. Then combinations of different variables were made in F3 to F6 showing increasing sexing accuracy. All variables resulted in an accuracy of O=98.1%; C= 93%. Therefore, F1, which includes 7 variables, predicts better than all the variables included.

Table No. 5: Standardized and unstandardized discriminant function coefficients, structure matrix, sectioning points in original samples.

Functions and Variables	B	Std. Coeff.	Str. Coeff.	Centroids	Average Accuracy	
					O	C
Stepwise analysis						
F1HBMETAC(L)	.140	.564	.774	M= 1.664	98.1	98.1
HBACROSST(R)	.124	.557	.761	F= -1.844		
TL(R)	.122	.511	.448	S.P= -.09		
RFL(L)	-.165	-.724	.383			
MFL(R)	.143	.586	.487			
IFL(R)	-.122	-.482	.432			
PL(L)	.040	.217	.513			
(Constant)	-26.604					
Direct analysis						
F2HBACROSST(L)	.208	1	1	M= 1.165	93.0	92.6
(Constant)	-20.253			F= -1.291		
				S.P=-.063		
F3HBACROSST(L)	.168	.805	.940	M= 1.240	94.0	94.0
AL(L)	.008	.367	.662	F= -1.373		
(Constant)	-23.289			S.P=-.066		
F4HBACROSST(L)	.152	.731	.905	M= 1.288	94.9	94.4
AL(L)	.006	.265	.637	F= -1.427		
TL(R)	.070	.294	.578	S.P=-.069		
(Constant)	-24.244					
F5HBACROSST(L)	.147	.705	.898	M= 1.297	95.8	95.8
AL(L)	.005	.207	.633	F= -1.437		
TL(R)	.059	.245	.628	S.P=-.07		
PL(R)	.027	.152	.574			
(Constant)	-24.702					
F6HBACROSST(L)	.158	.757	.883	M= 1.319	96.7	95.8
AL(L)	.006	.253	.622	F= -1.462		
TL(R)	.083	.349	.617	S.P=-.072		
PL(R)	.035	.198	.565			
IFL(L)	-.068	-.270	.536			
(Constant)	-24.151					
All variables	-	-	-	-	98.1	93.0

#B- Unstandardized Coefficient; Std. Coeff.- Standardized Coefficient; Str. Coeff.- Structure Coefficient; O- Original; C- Cross Validated; S.P- Sectioning Point; F- Function

Discussion

Identifying human individuals through biological profiling is one of the crucial tasks of a forensic investigator when any mutilated or unknown body is found. When techniques like DNA, and fingerprinting are not available, alternative methods of sex estimation can be used . Hands as a tool for individualisation, play an important role in anthropology as they provide valuable insights into the morphology, and population-specific equation that could be derived using them.

Therefore, the present study has been done to find the sexual dimorphism in the Haryanvi population.

Descriptive Analysis:

In this research, highly significant sexual dimorphism was found where male hand variables were larger than the females, in accordance with other studies **(Agnihotri *et al.*, 2005; Ibeachu *et al.*, 2011; Kanchan *et al.*, 2010; Kanchan *et al.*, 2010; Rastogi *et al.*, 2020).**

Discriminant Function Analysis:

A fundamental aspect of forensic anthropology is sex estimation for identification **(Varu *et al.*, 2016)** In the present study, the single best variable was HBACROSST(L) illustrating high accuracy. Several other studies also revealed the same variable predicting best accuracy as described in table 4 **(Howley *et al.*, 2018; Ishak et al.; Jee *et al.*, 2015; Kanchan and Rastogi, 2009; Singh *et. al.*, 2019; Varu *et al.*, 2016)**. Contrarily, **(Singh *et. al.*, 2019)** found 4DL as the best method for sexing accuracy **(Singh *et al.*, 2019).**

Table No. 6: Comparison of different methods of sex determination from hand measurements used by various researchers.

Population group	Study	Method	N	% of correct classification
Haryanvi (Indian)	Present Study	HBACROSST	M(113) F(102)	93
Gujrati (Indian)	(Varu et al.)	HB	200	82.0
Western Australia	(Ishak et al.)	HB	M(91) F(110)	93.3
H.P. (Indian)	(Singh et al.)	4DL	M(54) F(48)	80.8
Australian	(Howley et al.)	RHB	M(35) F(60)	90.6
Indian	(Kanchan and Rastogi)	LHB	M(230) F(270)	90.1
Korean	(S. C. Jee et al.)	MHB	M(167) F(154)	86.6

Population variation using z-score:

To study the extent to which the data are from the reference median in a given population, z score can be calculated **(Bulut *et al.*, 2023)** On comparing the Hand length with other population groups of the world using z-score values, the Nigerian **(Danborno and Elukpo, 2007)** and Gujrati population **(Varu et al., 2016)** recorded the greatest and shortest values respectively (table 5). The means of the Western Australian **(Ishak et al.; Jee et al., 2015)** Nigerian **(Danborno and Elukpo, 2007)** Australian **(Howley et al., 2018)** populations have longer hands than the Haryanvi population (z-score negative). Contrarily the average values of the Malaysian **(Zulkifly et al., 2018)** Gujrati **(Varu et al., 2016)**, Mauritius **(Agnihotri et al., 2005)** Slovak **(Uhrová *et al.*, 2015)**, Rajputs, **Indian (Rastogi *et al.*, 2008)** North Indian **(Krishan and Sharma, 2007)** Southern Chinese **(Tang *et al.*, 2012)**, Central Indian **(Charmode *et al.*, 2019)** and Southern Indian **(Rastogi *et al.*, 2008)** have smaller values than the Haryanvi groups (positive z score). Study done by Asha et al. (2012), Ishak et al. (2012) and in an Egyptian population revealed similar findings to that of the present study **(Aboul-Hagag et al., 2011; Asha et al., 2012; Ishak et al., 2012).** Notably, the range of hand length values within each population is essential for comprehending the diversity.

For Hand Breadth, the Malaysian population **(Zulkifly et al., 2018)** had the smallest hand breadth values among the population studied (71.1- 78.3 mm). This suggests that, on average, Malaysians have narrower palms than the other populations included in the study. On the other hand, the present study had the greatest hand breadth values suggesting larger palms than the other populations included, as indicated by z score and highly significant p values ($p<0.05$). These variations could be attributed to ethnicity, locomotor pattern, lifestyle or racial differences **(Ibrahim *et al.*, 2016).**

Table No. 7: Comparison of sex differences in hand anthropometric variables in different population groups.

Population group	Study	N	Males	Z Score Left	Z Score Right	P value Left	P value Right	Females	Z Score Left	Z Score Right	P value Left	P value Right
Hand Length (HL)												
Haryanvi (Indian)	Present study	M(113) F(102)	L- 194.54±9.17 R- 194.40±9.01	NA	NA	NA	NA	L- 177.60±9.27 R- 177.59±8.27	NA	NA	NA	NA
Malaysian	(Zulkifly et al.)	M(50) F(52)	L- 185.4±9.9 R- 185.1±9.4	5.56	5.90	0.00	0.00	L- 174.8±8.0 R- 173.0±8.2	1.94	3.27	0.05	0.00
Australian	(Howley et al.)	M(35) F(60)	L- 196.4±1.46 R- 196.1±1.47	-2.07	-1.92	0.04	0.05	L- 178.8±.9 R- 178.7±1	-1.29	-1.34	0.05	0.18
Western Australia	(Ishak et al.)	M(91) F(110)	L- 195.6±9.2 R- 195.4±9.3	-0.82	-0.77	0.41	0.44	L- 176.0±8.2 R- 175.9±8.2	1.33	1.49	0.19	0.14
Mauritius	(Agnihotri et al.)	M(125) F(125)	L- 189.0±8.7 R- 188.9±8.8	4.77	4.75	0.00	0.00	L- 172.2±9.3 R- 172.2±9.2	4.36	4.64	0.00	0.00
Nigerian	(Danborno and Elukpo)	M(250) F(150)	L- 199.3±9.3 R- 198.5±8.6	-4.36	-4.07	0.00	0.00	L- 183.2±7.7 R- 185.1±6.6	-6.83	-7.66	0.00	0.00
Egyptian	(Aboul-Hagag et al.)	M(250) F(250)	L- 195.0±9.2 R- 194.7±9.2	-0.44	-0.29	0.66	0.77	L- 181.7±9.1 R- 181.3±9.0	-3.78	-3.72	0.00	0.00
Slovak	(Uhrová et al.)	M(120) F(130)	L- 187.3±9.2 R- 187.0±8.9	6.01	6.30	0.00	0.00	L- 172.1±7.6 R- 172.1±7.5	4.84	5.23	0.00	0.00
Southern Chinese	(Tang et al.)	M(185) F(215)	L- 183.6±8.7 R- 183.7±8.8	10.19	10.03	0.00	0.00	L- 169.6±9.5 R- 169.9±9.5	7.12	7.42	0.00	0.00
Rajputs (Indian)	(Kanchan, Krishan, et al.)	M(120) F(120)	L- 183±9 R- 182±12	9.69	8.95	0.00	0.00	L- 168±8 R- 168±8	8.18	8.74	0.00	0.00
Indian	(Rastogi, Nagesh, et al.)	M(110) F(170)	L- 188.2±9.5 R- 188.1±9.6	5.07	5.05	0.00	0.00	L- 169.5±7.5 R- 169.7±7.8	7.48	7.78	0.00	0.00
North Indian	(Krishan and Sharma)	M(125) F(125)	L- 182.1±9.1 R- 182.4±9	10.45	10.23	0.00	0.00	L- 168±8.3 R- 168.3±8	8.11	8.51	0.00	0.00
Central Indian	(Charmode et al.)	M(500) F(500)	L- 189.6±12.7 R- 189±11.6	4.78	5.43	0.00	0.00	L- 171.1±9.9 R- 171.8±9.9	6.58	6.22	0.00	0.00
North Indian	(Asha et al.)	100	L- 194.6±11.2 R- 195.3±11.6	-0.03	-0.49	0.97	0.62	L- 177.4±9.0 R- 178.0±9.3	0.13	-0.26	0.89	0.79
South Indian	(Asha et al.)	100	L- 193.8±10.2	0.44	0.00	0.66	1	L- 174.7±10.1	1.71	1.77	0.09	0.08
			R- 194.4±11.3					R- 174.7±10.0				
North Indian	(Rastogi, Nagesh, et al.)	M(120) F(100)	L- 188.7±9.1 R- 188.8±9.1	4.88	4.718	0.00	0.00	L- 170.1±9.5 R- 170.3±9.4	5.68	5.85	0.00	0.00
South Indian	(Rastogi, Nagesh, et al.)	M(110) F(170)	L- 188.1±9.6 R- 188.2±9.5	5.12	5.00	0.00	0.00	L- 169.5±7.5 R- 169.7±7.8	7.48	7.78	0.00	0.00
Gujrati (Indian)	(Varu et al.)	M(100) F(100)	L- 178.0±9.8 R- 179.8±9.5	12.67	11.47	0.00	0.00	L- 165.7±8.7 R- 166.5±8.4	9.41	9.45	0.00	0.00
Hand Breath Meta Carpal (HB Meta C)												
Haryanvi (Indian)	Present study	M(113) F(102)	L- 92.36±4.30 R- 92.90±4.43	NA	NA	NA	NA	L- 81.39±3.72 R- 82.13±4.38	NA	NA	NA	NA
Malaysian	(Zulkifly et al.)	M(50) F(52)	L- 77.1±5.1 R- 78.3±5.6	18.42	16.31	0.00	0.00	L- 71.1±3.4 R- 72.5±3.7	17.19	14.33	0.00	0.00
Mauritius	(Agnihotri et al.)	M(125) F(125)	L- 84.2±4.0 R- 84.5±4.0	15.05	15.29	0.00	0.00	L- 74.2±3.7 R- 74.8±3.8	14.52	13.30	0.00	0.00
Western Australia	(Ishak et al.)	M(91) F(110)	L- 90.4±4.9 R- 91.0±4.8	2.95	2.91	0.00	0.00	L- 78.4±4.5 R- 79.3±4.5	5.29	4.64	0.00	0.00
Slovak	(Uhrová et al.)	M(120) F(130)	L- 85.1±4.5 R- 84.8±4.2	12.54	14.30	0.00	0.00	L- 75.9±5.6 R- 75.8±3.6	11.32	11.80	0.00	0.00
Nigerian	(Danborno and Elukpo)	M(250) F(150)	L- 86.8±9.2 R- 89.0±9.5	7.80	5.33	0.00	0.00	L- 77.2±4.6 R- 78.2±4.9	7.96	6.66	0.00	0.00
Egyptian	(Aboul-Hagag et al.)	M(250) F(250)	L- 81.4±4.0 R- 81.3±3.9	22.91	23.95	0.00	0.00	L- 71.7±4.1 R- 71.7±4.0	21.51	20.77	0.00	0.00
Southern Chinese	(Tang et al.)	M(185) F(215)	L- 83.3±9.1 R- 83.4±9.3	11.55	11.86	0.00	0.00	L- 71.2±5.3 R- 72.1±5.6	19.74	17.36	0.00	0.00
Australian	(Howley et al.)	M(35) F(60)	L- 89±.8 R- 90±.8	7.81	6.62	0.00	0.00	L- 79.7±.52 R- 80.4±.55	4.51	3.94	0.00	0.00
North Indian	(Asha et al.)	100	L- 81.7±4.3 R- 82.8±4.6	14.55	13.07	0.00	0.00	L- 72.7±4.1 R- 73.3±4.3	12.65	11.82	0.00	0.00
South Indian	(Asha et al.)	100	L- 81.9±3.7 R- 82.5±4.1	15.77	14.56	0.00	0.00	L- 72.3±3.1 R- 73.1±3.2	15.87	14.40	0.00	0.00
North Indian	(Rastogi, Nagesh, et al.)	M(120) F(100)	L- 79.6±3.8 R- 80.5±3.7	23.89	23.11	0.00	0.00	L- 70.6±3.3 R- 71.9±3.3	21.81	18.77	0.00	0.00
South Indian	(Rastogi, Nagesh, et al.)	M(110) F(170)	L- 80.3±3.9 R- 81.1±3.9	21.89	21.13	0.00	0.00	L- 70.9±3.3 R- 72.3±3.3	23.47	19.58	0.00	0.00
Gujrati (Indian)	(Varu et al.)	M(100) F(100)	L- 80.9±6.0 R- 82.6±5.3	15.79	15.28	0.00	0.00	L- 71.5±4.3 R- 72.7±3.3	17.47	17.30	0.00	0.00

Conclusion

Hence the present study reveals the potential of hand as an additional tool to estimate the sexual dimorphism in Haryanvi population using linear measurements and simple invasive techniques. When a mutilated body is found, the discriminant functions generated from simple statistical methods using hand measurements can provide a valuable information to estimate sex of unknown. Furthermore, the sexing accuracies specific for Haryanvi population can be helpful in forensic, clinical, medicolegal and anthropological studies.

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