SEX DETERMINATION USING FINGERPRINTS DERMATOGLYPHICS AMONG NORTH INDIAN POPULATIONS

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Abstract

Fingerprints are the most reliable and dependable legal biometric evidence. In the present study, 300 healthy and consenting adults aged between 18-25 years of Delhi, India were asked for their 10-digits fingerprints. The aims were to determine the frequency distribution of various fingerprint patterns with establishing most dominant pattern type. Also to find out whether any statistically significant sex difference exists. It was found that loops were predominantly higher (48.66%) whereas whorls were second highest (34.34%) while arches were least common (17.00%) amongst both male and female sexes. The ridges were counted in the left of centre (LoC) area of right thumb and mean value was calculated. The results have shown that a fingerprint ridge density 10-17 ridges/25 mm^2 is more likely to be of male origin while fingerprint ridge density 18-25 ridges/25 mm^2 is more likely of female origin. Thus suggests a positive significance of epidermal ridge density between sexes. The results of the study may provide useful information about the sex of the perpetrator in forensic case investigations while narrowing down their search from a large sample.

Keywords: *Fingerprints, ridge density, pattern types, north Indian population.*

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1. Introduction

Dermatoglyphics is defined as the scientific study of epidermal ridges and their configuration on the volar aspect on the palmar and plantar regions [1]. The ridge patterns on thumb and fingers depend upon cornified layer of epidermis as well as dermal papillae. The characteristic patterns of epidermal ridges are differentiated in their definitive forms during third and fourth months of foetal life [2]. Faulds[3] mentioned that the pattern of these papillary ridges remain unchanged during the lifetime of an individual. Galton [4] classified the types of fingerprints depending upon their primary pattern as loops (60-65%), whorls (30-35%) and arches (0-5%). Cummins found that configuration of ridge patterns are determined partly by heredity and partly by accidental or environmental influence, which produce stress and tension in their growth during foetal life [1]. Fingerprints are unique to every single individual and are formed in the human foetus before birth of a child in this world. It does not change throughout the lifetime unless damage to the dermal layer of skin occurs. The pattern of fingerprint becomes fixed when a person is about 14 years or older. Therefore, no two fingers are found to have identical prints not even identical twins [1, 4-6, 8]. Fingerprints of an individual have been used as one of the vital evidences for personal identification in both civil as well as criminal cases because of their unique property of absolute identity. Therefore, fingerprints found at scene of crime can be used to confirm or reject the association of a suspect with objects found at crime scene. In addition, judiciary puts higher value on fingerprints than other physical evidence.

The distribution of fingerprint patterns has been found to be varying amongst various populations and ethnic groups. If a fingerprint is encountered as evidence, matching of minutiae comes second, the primary task being the classification of the pattern present on the print, which can thereafter be used for narrowing down the suspect pool by eliminating the suspects with any other pattern type other than the one found on the crime scene. Thereby, reducing the burden on the investigating officer and saving on time. In the past, attempts have been made by researchers to study the distribution of fingerprint patterns in various populations and ethnic groups. The present study was aimed to determine the detailed frequency distribution of various fingerprint patterns, establish the most and least predominant pattern and to find out existence of any statistically significant sex differences in the North Indian population. There have been many studies conducted in the past on sex determination through fingerprint ridge density [7,9,11,14-17,28-32] and reported higher epidermal ridge density in females as compared to males. However, no such study has been conducted on Delhi population so far, hence the present study.

2. Materials and Methods

(i) Sample size:

This study was carried out on 300 students (150 males and 150 females) in the age group of 18-25 years from Delhi, India. All students were informed about the purpose and nature of the study and obtained wilful written consent before taking prints. Students with permanent scars on thumb or fingers, any hand deformity due to injury or disease, any birth defect or having worn fingerprints, extra webbed or bandaged fingers were all excluded from the study. There was no special attempt made to choose the subjects, they were chosen on the basis of stability and cooperative nature.

(ii) Procedure:

For taking fingerprints, ink method suggested by Cummins [1] was used. Each subject was asked to wash his/ her hands with soap and water and pat dry with hand towel. Thumb impression ink (Kores® India) was evenly spread on a white ceramic tile (slab) with the help of a rubber roller. The subjects were asked to first roll their fingertips on the ink slab and then carefully, slowly and serially, on the allotted spaces on the 10-digit fingerprint identification slip, with a relaxed hand. Any external pressure was avoided during the process to ensure that no smudging of prints occurs. Care was taken to ensure that all the fingerprints were taken only in the respective spaces provided on the Performa. The same procedure was repeated for all the subjects.

(iii) Analysis:

The fingerprints thus obtained were then classified according to Galton's classification [4] into loops, whorls and arches. Various dermatoglyphic pattern indices such as Pattern intensity index, Dankmeijer's index and Furuhata's index[9] were calculated using following equations.

Pattern Intensity Index

$= \frac{(2 \times \%\ whorl + \%\ loop)}{10}$

Dankmeijer's Index

$= \frac{(\%\ arch)}{(\%\ whorl)} \times 100$

Furuhata's Index

$= \frac{(\%\ whorl)}{(\%\ loop)} \times 100$

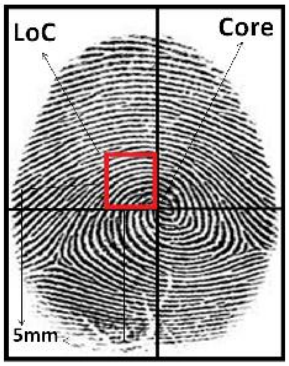

Figure 1: depicts the ridge count area selected for the study on right thumb

For ridge density analysis, an area of 25mm^2 was selected near left of core of the thumbprint pattern on right hand thumb. The epidermal ridges of both males and females were counted carefully within a square of 5mm x 5mm drawn on a transparent film fixed to the lens, as shown in **Figure 1**. Counting started from one corner of the square to the diagonally opposite corner. Dots were not counted while fork, bifurcation and island were counted as two ridges. This value represented the number of ridges/25 mm^2 and reflects the ridge density value. Applying the t-test, the differences in the ridge densities of males and females at right thumb LoC were calculated, at ($p < 0.01$) using SPSS 17.0. software. The likelihood ration (LR) was calculated to obtain the probability inferences of gender, based on ridge density values. The likelihood ratio is based on Baye's theorem [33].

LR = Probability of given fingerprint originating from male contributor (C) / Probability of given fingerprint originating from female contributor (C')

3. Results and Discussion

A total of 3000 fingerprints were studied and their patterns identified. Overall, loops were found to be the most common pattern mean 48.66% followed by whorls mean 34.33% and then arches mean 17%. Fingerprints pattern distribution amongst males and females is shown in **Table 1** and **Graph 1**. And a detailed frequency distribution of different fingerprint patterns for individual digits in both hands amongst males and females is shown in **Table 2**.

Table 1: Fingerprints pattern distribution amongst males and females.

Pattern types	**Loops**	**Whorls**	**Arches**
Males *(n=150)*	49.33%	34.00%	16.66%
Females *(n=150)*	48.00%	34.66%	17.34%

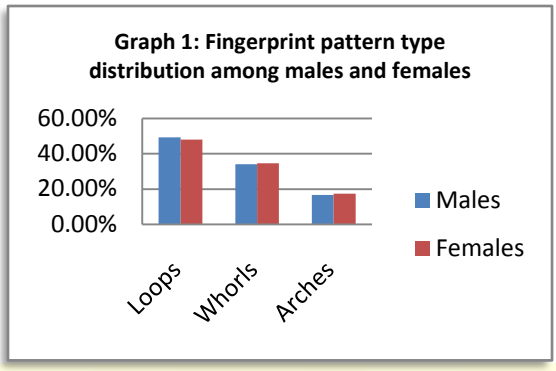

Table 2: Frequency distribution of digital patterns w.r.t Right and Left hand

Pattern type	Right hand (300)					Left hand (300)				
	RT	RI	RM	RR	RL	LT	LI	LM	LR	LL
Loops (L)	159 (53%)	178 **(59.3%)**	201 **(67%)**	150 (50%)	201 **(67%)**	165 (55%)	159 (53%)	192 **(64%)**	150 (50%)	192 **(64%)**
Whorls (W)	133 **(44.3%)**	99 (33%)	81 (27%)	141 **(47%)**	90 (30%)	102 (34%)	138 **(46%)**	78 (26%)	144 **(48%)**	80 (26.6%)
Arches (A)	08 (2.6%)	23 **(7.6%)**	18 (6%)	09 (3%)	09 (3%)	33 **(11%)**	03 (1%)	30 **(10%)**	06 (2%)	28 **(9.3%)**

The mean of all 10-digits of both right as well as left hands of both the sexes were taken to calculate the predominance of pattern types. As shown in **Table 1**, it is observed that 74 out of total 150 males (49.33%) have loop patterns predominantly on their 10-digit finger prints at the same time 72 out of 150 females (48%) also have loop patterns. About 34% of total male and female population have shown to have whorls patterns with count of 51 males and 52 females. The least encountered fingerprint pattern was arch, with only 25 males (mean 16.66%) and 26 females (mean 17.34%) in 10-digits. It can be seen from the observations above that most of the Delhi population has loops> whorls> arches, in that order irrespective of the sex group they belong. This is in accordance to the works conducted by Kanchan et al.,[12] Chattopadhyay et al.[23] It is further observed from **Table 2** that loops are predominant on right index, right middle, ring little as well as on left middle and left little fingers. The arch pattern is dominant on right index, left thumb, left middle and left little fingers. Whereas whorl patterns could be mostly encountered on right thumb, right ring, left index and left ring, which is in accordance to the observations of Eboh,[10] and Boroffice[26]. The evaluated results of the present study are in accordance with the studies conducted by various other researchers [7,9-12,14,22-26] who also found loop pattern to be most common in the various populations studied by them as shown in **Table 3**. However, the results of our study are found to be in contrast to the studies conducted by some researchers [13,15-17,21] who reported whorls to be the most

common pattern, followed by loops and arches in both the hands of males and females. This contrast in result could be due to the topological difference, racial or genetic variations amongst different population groups [1,4,34].

Table 3: Comparative chart of fingerprint patterns type of present study w.r.t various other populations.

Population/ethnic group	Sex	N	Fingerprint pattern types			Authors
			Loops	Whorls	Arches	
North Indian population	M	150	49.33	34.01	16.66	**Present study**
	F	150	48	34.66	17.34	
South Indians (India)	M	250	51.4	41.08	5.68	Nithin et al. [7]
	F	250	38.16	35.36	4.52	
Annang ethnic group (Nigeria)	M	200	41.7	42.9	15.4	Ekanem et al. [20]
	F	200	50.7	19.5	22.6	
Ijaws (Delta State, Nigeria)	M	100	33.98	21.03	0.47	Anibor et al.[19]
	F	100	17.68	27.26	1.51	
Aniomas (Southern Nigeria)	M	176	54.9	27.6	17.5	Eboh [10]
	F	164	54.4	29.1	16.5	
Urhobos (Southern Nigeria)	M	224	53.9	29.4	16.7	
	F	256	58.3	28.9	12.8	
Medical Students (Gangtok, India)	M	55	56.8	38.7	4.5	Kanchan et al [12]
	F	55	58.2	37.3	4.5	
Rajput (Himachal Pradesh, India)	M	50	49	49	2	Singh and Garg [14]
	F	50	53.33	46.86	1.81	
Sinhalese (Sri Lanka)	M	217	58.52	36.54	4.93	Wijerathne et al. [9]
	F	217	60.92	34.52	4.56	
Rarhi Brahmins (Bengal)	M	100	53.8	43.9	2.3	Chattopadhyay et al. [23]
	F	38	64.47	31.32	4.21	
Tunisians (Tunisia)	M	233	61.72	31.31	7.08	Namouchi [11]
	F	110	63.54	27.74	8.63	
Danguria Tharu of Uttar	M	379	54.69	41.42	3.87	Srivastava [24]

Population/ethnic group	Sex	N	Fingerprint pattern types			Authors
			Loops	Whorls	Arches	
Pradesh (India)	F	300	55.33	40.5	4.16	
Black Americans (USA)	M	100	63.1	33.6	3.3	Qazi et al.[25]
	F	100	59.7	31.3	8.2	
Nigerians (Nigeria)	M	400	54.14	30.05	16	Boroffice [26]
	F	400	52.31	25.3	22.4	
Indigenous black Zimbabweans (Zimbabwe)	M	135	77.77	12.23	10	Igbigbi [22]
	F	135	85	5	10	
Rengma Nagas of Nagaland (India)	M	104	46.96	52.19	0.49	Banik et al. [17]
	F	103	42.52	55.69	1.79	
Dhimals of North Bengal (Bengal)	M	101	42.16	55.10	2.75	Biswas [16]
	F	101	48.24	50.19	1.57	
Tibetans (Tibet)	M	156	38.99	60.24	0.76	Tiwari et al. [15]
	F	150	49.13	48.67	2.2	
Muzziena Bedouin (South Sinai)	M	170	49.2	49.1	1.7	Karmakar et al. [18]
	F	48	48.2	50.3	1.6	
Samoan (New Zealand)	M	100	43.6	55.6	0.8	Cho [13]
	F	93	33.7	65.6	0.7	
Australian Aborigines in the Northern Territory (Australia)	M	114	42.6	56.7	0.8	Cho [21]
	F	90	47	51.2	1.7	

The various pattern indices in the north Indian population have been calculated, listed and compared to other available data from other workers as shown in **Table 4**. In the present study, the values of pattern intensity index are in accordance with values obtained by Wijerathne et al.[9] and modestly lower in comparison to the values obtained from other population groups but fairly comparable[13-16]. The values of Dankmeijer's index for the north Indian population was found to be very high in comparison to other population groups[9,13-16] while that of Furuhata's Index is somewhat comparable to Singhalese population[9]. In agreement to the statement of Newman [27], the various indices showed great variability in terms of the various populations, as could also be seen within different population groups from **Table 4**.

Table 4: A comparison of the dermatoglyphics pattern indices of North Indian population with other population groups.

Population	Pattern Intensity Index	Dankmeijer's Index	Furuhata's Index	Author(s) & Year
North Indian population	13.06	15.64	64.52	**Present study**
Rajputs (India)	14.85	3.73	109	Singh and Garg [14]
Sinhalese (Sri Lanka)	13.08	13.35	59.55	Wijerathne et al. [9]
Samoan (New Zealand)	15.99	1.32	156.59	Cho [13]
Tibetans (Tibet)	15.3	2.88	126.78	Tiwari et al. [15]
Dhimals (North Bengal)	15.05	4.1	116.49	Biswas [16]

As for ridge density, the present study showed that the males tend to have the lesser number of ridges when compared to females. The ridge density of males lie between 10-17 ridges/ 25 mm^2 with maximum number of males having ridge density between 14-17 with no male had ridge count of more than 18. On the other hand, ridge density of females lies between 18-25 ridges/ 25 mm^2 with maximum females having ridge counts of 21-24 and no female found to have ridge count less than 16. The mean value of ridge count for male was 15.78 and that of female were 16.36 **(Table 5).** In this study the LR values tend to decrease in males and when we see the other LR value (C'/C) in females, it is found that it increases drastically from 18 ridges onwards **(Table 6).** The t-test results show that the males have significantly lesser ridge density than females at $p<0.001$ value.

Table 5: Shows Descriptive Statistics of Ridge Density in both males and females

Statistical variable	Males	Females
Mean	15.78	16.36
Standard Deviation	1.29	1.72
Minimum	10	17
Maximum	17	25
Range	10-17	18-25

Table 6 Probability Density and Likelihood Ratio Sex wise Distribution of epidermal Ridge Count on Right Thumb print

Ridge count	Males	(%)	Females	(%)	Probability density		Likelihood ratio	
					Male (C)	Female (C')	LR (C/C')	LR (C'/C)
10	1	0.66	-		0.0066	-	66	0.01
11	2	1.34	-		0.0134	-	134	0.007
12	3	2	-		0.02	-	200	0.005
13	6	4	-		0.04	-	400	0.003
14	30	20	-		0.2	-	2000	0.001
15	45	30	-		0.3	-	3000	0.001
16	48	32	-		0.32	-	3200	0.001
17	15	10	1	0.66	0.1	0.0066	15.15	0.066
18	-		2	1.34	-	0.0134	0.007	134
19	-		3	2	-	0.02	0.005	200
20	-		6	4	-	0.04	0.003	400
21	-		27	18	-	0.18	0.001	1800
22	-		45	30	-	0.3	0.001	3000
23	-		42	28	-	0.28	0.001	2800
24	-		15	10	-	0.1	0.001	1000
25	-		9	6	-	0.06	0.001	600
Total	150	100	150	100				

At $p<0.001$, it is evident from the table above **(Table 6)** that t-test results are highly significant at ridge counts 14-16 for males while it is vastly significant at ridges 21-25 for females. This study demonstrates that there is a prominent significant difference in the epidermal ridge density between males and females of Delhi population, northern part of India. It shows similar trends in sex difference as the other studies over the past conducted on other races and regions. It, therefore, shows that this trend is universal among all races. Thus, even when the areas analysed for thumbprint ridge density in our study differ from that of the earlier studies [28-34] the basic quantitative differences remain same, i.e., females have a higher finger (thumb) print ridge density than males which is in accordance with earlier studies on different ethnic groups[35-38]. Ridge thickness and furrows are the two important factors which determine the density of ridges. Past researches [39-40] on the ridge thickness in fingerprints showed that males have coarser finger ridges than females which suggest that males will have fewer ridges in a given area than females and thus

a lower ridge density. The higher fingerprint ridge density in females is attributed to the fact that females tend to have finer epidermal ridges than males [41].

4. Conclusion

The identification by fingerprints is an infallible means of personal identification in both civil as well as criminal cases. The present study was conducted in an attempt to describe the ridge densities of epidermal thumb ridges, and it has been successful for supporting the hypothesis that women tend to have a statistically significant greater ridge density than men. The results have shown that a ridge count of 10-17 ridges/25 mm^2 are more likely to be of male origin and that of 18-25ridges/25 mm^2 are likely to be of female origin. Thus, for an unknown thumb print, it may be concluded that if the ridge density is between 14-16 ridges/25 mm^2 it is most likely to be of a male whereas, if the ridge density is between 21-24ridges/25 mm^2 it shall be from female origin. This result is also supported by various studies conducted in past over different population groups and on different area selected on fingerprint for the study [28-32]. The outcome of ridge density analysis from right hand thumbprint shows significant difference between sexes, with women having significantly higher ridge density than men. It would become universally accepted, when more of such researches would be carried out in other parts around the world. This study would lend a helping hand to the investigating officer in directing their search to a particular gender and save time while catching the criminals.

Furthermore, it can be concluded from the quantitative results obtained from the present study that the common ridge pattern amongst males and females was loop followed by whorl with the least common found to be arch. This is in accordance with the results of study conducted by Nithin et al.,[7] Eboh,[10] Anibor et al.[19] and Boroffice [26]. Detailed classification and frequency distribution of fingerprint patterns were compiled and evaluated for Delhi population of north India. However, it could not establish a statistically significant difference between sexes for the occurrence of patterns on all ten fingers. However, the results of various indices were calculated and compared to the available data for various other populations and ethnic groups from India and around the world and was found in accordance with most [7, 9-10]. Moreover, it is proposed to take up a larger sample size for more precise results.

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