JOURNAL OF FORENSIC MEDICINE SCIENCE AND LAW

Official Publication of Medicolegal Association of Maharashtra

Editor-in-chief
Dr Ravindra Deokar

Associate Editors
Dr Sadanand Bhise
Dr Sachin Patil

**MULTISPECIALITY, MULTIDISCIPLINARY, NATIONAL
PEER REVIEWED, OPEN ACCESS, MLAM (SOCIETY) JOURNAL
Indexed with Scopus (Elsevier)**

Original Research Article

Sexual Dimorphism in Fingerprint Ridge Density

Pratapsingh Rathod[a*] , Pradyumna Powalkar[b]

[a]Associate Professor, Forensic Medicine; [b]Tutor, D. Y. Patil Medical College, Kolhapur, Maharashtra, India.

Article Info

Abstract

Background & Aim: Aim of the study was to find the relationship between individual sex and fingerprint ridge density. As a part of identification, dermatoglyphics plays an important role and attempt is made to utilize the fingerprint ridges to speculate the individual gender. **Material & Methods:** The present prospective study was conducted on 200 participants (100 male and 100 female) between age group of 18 to 21 years. Fingerprint ridge density in $25mm^2$ square of fingerprint of all the fingers of participants were analysed for the study. **Results:** The ridge density ranged from 11 to 17 ridges/$25mm^2$ with mean of 14.06 in males and 13 to 19 ridges/$25mm^2$ with mean of 16.05 in females. The likelihood ratio is high for prints of 12 ridges (C/C^1) in males and very high for prints of 19 ridges (C^1/C) in females. Analysis of LR and favoured odds shows that a ridge density of ≤13 ridges/$25mm^2$ is more likely to be of male origin and ridge density of ≥17/$25mm^2$ is more likely to be of female origin. **Conclusion:** As seen from favoured odds ridge density of ≤13 ridges/$25mm^2$ is more likely to be of male origin and ridge density ≥17/$25mm^2$ is more likely to be of female origin. The results varied from place to place and country to country, as seen in different studies and standardisation is necessary to use ridge density as an identification tool.

1. Introduction

Dermatoglyphics or Study of fingerprint has been present since centuries, it has been used to identify individual because of its uniqueness in itself. Every fingerprint is unique and is used to identify individual from thumbprint on a document to advanced biometrics for even online transaction. The fingerprint pattern is different, even in identical twins, and are distinctive and permanent in individuals.[1] Fingerprint remains ubiquitous throughout life and forms the most reliable criteria of identification. The pattern makes their appearance as early as 10 weeks of intrauterine life.[2] These patterns are developed entirely in utero and are permanent throughout their lifetime. Injuries like cuts, burns and, bruises can temporarily damage the quality of fingerprints but when fully healed, patterns are restored.[3] In crime scene many times the fingerprints, palm or sole prints are not found in proper formation or only available partially, then the ridge counting can be a useful tool for identification. Sex determination is one of the important identification parameters along with age, stature, race.[4]

*Corresponding author: Dr Pratapsingh Rathod, Associate Professor, Forensic Medicine, D. Y. Patil Medical College, Kolhapur, Maharashtra, India. Email: drpratapsir@gmail.com; (M): +91-9113970856

Though fingerprint ridge density is individualistic, it is seen to have sexual dimorphism as first observed by study conducted by Acree.[5] Following him many studies have been conducted to determine sex from fingerprint ridge density in different countries showing similar results. Among all these studies though it shows similar results standardization is yet to formed and it is seen to vary from one region to another region and from one race to another race. Owing to variation in these studies present study aims to append to existing data.

2. Methodology

Study was conducted on 200 participants in age group of 18 to 21 years (100 Male and 100 Female) taking into consideration of 10% of population falling within 18 to 23 years age group (95% confidence level and 5% margin error). In this age group growth cessation in adulthood minimizes the ridge width affection, and not practicing a manual work reduces the chances that epidermal ridges are affected.[6] Informed consent was taken after procedure and objective of study was clearly explained. Participants with permanent scars on fingers, with any hand deformities due to injury, birth defects in hand, polydactyly individuals, those having worn finger-prints, webbed fingers, were excluded from the study since it would affect the statistical outcome.

Participants were asked to wash their hands with soap and water and dry it before proceeding to the study. Then participants demographic data was recorded mainly the age and sex for analysis. Plain Fingerprint were taken on clean sheet of paper by pressing his/her fingertip lightly on the stamp pad and then to the paper of all ten fingers. Care was taken to avoid smudging of the prints. Each fingerprint was photographed (**figure 1 & 2**) using macro lens camera with reference scale of each finger of each participant. Photographed fingerprints were uploaded in computer and using scale as reference a 5 mm × 5 mm square were placed on the left and the right upper portions of fingerprint core (upper radial side) of right and the left fingers respectively. Ridges were counted in the $25mm^2$ square along the diagonal, with specific criteria were observed during the counting procedure such as the dots, were not counted, and the handle of the fork and a lake was counted as two ridges.[7] Mean of all ten fingers were calculated and used as observed ridge density for further analysis. Descriptive statistics, t-test, likelihood ratio, and favored odds were analyzed using SPSS software.

Figure 1: Photographed fingerprints (Male)

Male

Figure 2: Photographed fingerprints (Female)

Female

3. Results

In the present study 200 subjects participated with equal ratio of male and female between 18 to 21 years of age. After tabulating and analysing the observer ridge density of males ranged from 11 to 17 with mean ridge density of 14, in females it ranged from 13 to 19 with mean ridge density of 16. (Tabel 1). Beyond 17 ridges count the number of males

decreases rapidly and after 17 there are no males. Opposite to this female ridge count started from 13 and increases up to 19 ridge count. Table 2 shows t-Test for Male and Female where t-value was -7.740 with degree of freedom (df) 198 when equal

variances are assumed and 196.689 when equal variance not assumed with p<0.0001, suggesting significant difference between the means of the male and female when compared.

Table 1: Frequency distribution and Descriptive statistics of Ridge density in Male and Female

Frequency	11	12	13	14	15	16	17	18	19	Total	Minimum	Maximum	Mean	S.E. Mean	Std deviation
Male	9	12	18	15	23	17	6	0	0	100	11	17	14.06	0.172	1.716
Female	0	0	9	15	22	13	13	13	15	100	13	19	16.05	0.191	1.914

Table 2: Independent sample t-Test for Male and Female

	T-Test for Equality of Means						
	t	df	Sig(2-tailed)	Mean Difference	Std. error difference	95% Confidence Interval of the Difference	
						Lower	Upper
Equal variances assumed	-7.740	198	<0.0001	-1.990	0.257	-2.497	-1.483
Equal variances not assumed	-7.740	195.689	<0.0001	-1.990	0.257	-2.497	-1.483

Table 3: Probability density and Likelihood Ratio from ridge density in Male and Female

Ridge Density in 25mm^2	Probability Density		Likelihood Ratio		Favoured Odds	
	Male(C)	Female(C^1)	LR (C/C^1)	LR (C^1/C)	Male	Female
11	0.05	0.01	5	0.20	0.83	0.17
12	0.11	0.02	5.50	0.18	0.85	0.15
13	0.19	0.06	3.17	0.32	0.76	0.24
14	0.23	0.12	1.92	0.52	0.66	0.34
15	0.2	0.18	1.11	0.90	0.53	0.47
16	0.12	0.21	0.57	1.75	0.36	0.64
17	0.05	0.18	0.28	3.60	0.22	0.78
18	0.02	0.12	0.17	6.00	0.14	0.86
19	0	0.06	0	-	0	1

Table no. 4: Comparison of ridge density among different studies with present study

Ref No.	Study	Number of Subjects	Age	Min to Max fingerprint ridge	Mean Ridge density	Favoured odds	Population Region
6	Intira et al	100 Males 100 Females	>18 yrs	Male: 13-19 Female: 14-20	Male: 15.81 Female: 16.58	Male: <14 Female: >19	Thais
8	Kandel et al	350 Males 350 Females	18 to 30 yrs	Male: 10-16 Female: 13-20	Male: 13.82 Female: 15.36	Male: <13 Female: >16	Nepal
9	Regine et al	150 Males 150 Females	18-40 yrs	Male: 17.9 to 18.8 Female: 19.32 to 20.78	Male: 18 Female: 19.72	NA	Filipinos
11	Sudesh et al	250 Males 250 Females	18-60 yrs	Male: 11-15 Female: 12-15	Male: 12.8 Female: 14.6	Male: <13 Female: >15	Karnataka
12	Lalit et al	125 Males 125 Females	18-60 yrs	Male: 11-15 Female: 11-14	Male: 11.9 Female: 14.1	Male: <12 Female: >14	Uttarakhand
13	Nithin et al	100 Males 100 Females	18-81 yrs	Male: 10-16 Female 11-19	Male: 12.79 Female: 14.81	Male: <13 Female: >15	South India
14	Neeti et al	100 Males 100 Females	18-30 yrs	Male: 9-15 Female: 12-19	Male: 11.58 Female: 14.56	Male: <12 Female: >14	Central India
15	Sucharitha et al	60 Males 60 Females	<18 yrs	Male: 124-134 Female: 145-153	Male: 128.5 Female:148.67	NA	Andhra Pradesh
16	Kewal et al	97 Males 97 Females	18-25 yrs	Male: 13-20 Female: 14-21	NA	NA	North India
#	Present study	100 Males 100 Females	18-21 yrs	Male: 11-17 Female: 13-19	Male: 14.06 Female: 16.05	Male: <13 Female: >17	Kolhapur

From the observed ridge density, probability density for male (C) and female (C^1) was calculated as shown in Table 3. From probability density, Likelihood Ratio (C/C^1) and (C^1/C) was calculated. It was found that likelihood ratio is high for prints of 12 ridges (C/C^1) in males and very high for prints of 19 ridges (C^1/C) in females. Analysis of LR and favoured odds shows that a ridge density of ≤13 ridges/25mm^2 is

more likely to be of male origin and ridge density of ≥17 25mm^2 is more likely to be of female origin.

4. Discussion

Fingerprints are gold standard in identification, detailed study of individual ridges to study of individual sweat pores are done to help in identification. Studying ridge density is also shown to statistically able to identify sex as seen in studies conducted throughout the world. The present study

broadens the data of sex determination from ridge density in locality of Maharashtra, since results of studies conducted in different regions shows some similarities and some dissimilarities. In present study results shows the likelihood ratio in males is high for prints of 12 ridges and in females it is very high for prints of 19 ridges. The favoured odds for male increases from 13 ridge count in males and 16 ridge count in females, this shows that ridge density of ≤13 ridges/25mm^2 is likely to be male and ridge density ≥17/25mm^2 is likely to be female, which can be seen from favoured odds. If we compare these results with studies done internationally like one of the studies done in Thai population[6] of 260 subjects (130 male and 130 female) showed ridge density in male ranged from 13 to 19 with mean ridge density of 15.81, in female ridge density ranged from 14 to 20 with mean ridge density of 16.58. In analysing likelihood ratio, it is seen that fingerprint ridge density of ≤16 ridges/25mm^2 to be male origin and ≥ 17 ridges/25mm^2 to be of female origin. This is comparable to present study, in which mean female ridge density is 16.05 and in favoured odds for females of >17 ridges/25mm^2 is likely to be of female. Noemi[8] in their study in Argentina of 335 individuals had similar results where females presented greater ridge density than males. Jwala Kandel et al[9] did study in Nepal of 700 medical students (350 males and 350 females between 18 to 30 years). Results showed mean ridge density of males was 13.82 and females was 15.36, when probability density was calculated it showed ridge density <13 ridges/25mm^2 (C/C1=5.75, P=0.86) and >16ridges/25mm^2 (C1/C=4.29, P1=0.84) have higher probability of originating from males and females respectively. Comparing to present study, our study population is less but it shows similar results for i.e., <13ridges/25mm^2 likely to be male and ridge density of >17ridges/25mm^2 is likely to be female. Regine[10] in Filipinos studied fingerprints of 300 volunteers of 18-40 age group. Study found ridge density to be sexually dimorphic (p < 0.001), with an average of 17 ridges / 25 mm^2 recorded among males and 20 ridges/25 mm^2 among females. Richard[11] did similar study on same Filipino population with different result were <13 ridge/25 mm^2 was likely to be male and > 15 ridges / 25 mm^2 this shows that even in same population there are variation present and extensive studies will help in standardising of identification of sex from ridge density.

Sudesh[12] in Mauritius did study on 500 subjects (250 Male and 250 female) showed similar results that a finger print ridge of <13 ridges/25 mm^{2}is more likely of male origin and finger print ridge of > 14 ridges/25 mm^2 is more likely of female origin. Mean ridge density of males was 12.8 to that of female was 14.6. In this study there is not much variation in ridge density but sample population is comparatively larger which may suggest that as sample increases, the mean and likelihood ratio of male and female is difficult to compare.

Many studies have also been done in India with common results of higher ridge density in female in comparison to males. Studies like Lalit et al [13] on 250 students showed male mean density of 11.9 and female mean density was 14.1 and study concluded that < 12 ridges/25 mm^2 are more likely of male, comparing to female it was > 14 ridges/25 mm^2. Nithin[14] studied and compared fingerprints of all fingers in 200 subjects in south Indian population and found similar results, in which mean density in males was around 12 and mean in females was around 14. Observed ridge density of <13 ridges/25 mm^2 was likely to be of male and > 14 ridges/25 mm^2 was likely to be of female. As seen in these studies though results vary, there is significant difference between ridge density of male and females and they correlate with the present study. Neeti[15] in central India conducted study on 200 subjects, but used only thumbprint for the study and showed mean ridge in male of 11.58 and mean ridge density in females was 14.56, and concluded that less 12 ridges/25 mm^2 is likely to be male and > ridges/25 mm^2 likely to be female. This study did not use all fingers but overall showed similar results of higher ridge density in females.

Sucharita[16] studied 120 medical students of equal gender and analysed fingerprint ridge density of left and right hand separately and added their ridges of all ten fingers for analysis and found mean ridge density among the females (148.67) is higher than in males (128.5). Though methodology is different from present study their results are similar. Kewal[17] in their study of 194 students of 18-25 yrs age group studied the ridges of ulnar and radial side of fingers and found ridge count between 13-14 in males and 14-21 in females, though it doesn't correlate with this study but it shows ridge density is higher in females as compared to males as seen in our study. Garg et al shows that the general distribution of the primary fingerprint pattern is related to gender and blood group 'B'.[18] Some researchers used other method for sex determination. [19,20]

In a totally different study, A comparative study was done of different articles comparing fingerprint ridge densities among them in different region of Indian and found that there is a significant difference in the epidermal ridge density between males and females of Indian origin and this comparison and analysis shows very much similar trend in ridge density.[21] In all these studies results have statistical significance and are comparable, rather than number specific results which are not comparable. If only statistical analysis of different studies is compared with present study it shows significant similar results

5. Conclusion

To conclude finger density can be used to asses sex to some extent. Variation in ridge density from male to female may be related to difference in build or body surface area and ridges may be more concentrated in female's comparative to males, though this may not be confirmed from present study. The results vary from place to place and country to country, as seen in different studies and standardisation is necessary to use ridge density as an identification tool.

Ethical Clearance: IEC approval was taken from the Institutional Ethical committee.
Contributor ship of Author: All authors equally contributed.
Conflict of interest: None to declare.
Source of funding: None to declare.

References:

1. Reddy KSN, Murthy OP. The Essentials of Forensic Medicine and Toxicology. 35th ed. Jaypee Publisher; 2024. p. 62-3.
2. Sree H, Raju Y, Varma MR, Krishna PR, Deepika I. Dermatoglyphics of medical students of a tertiary teaching hospital in Srikakulam District, Andhra Pradesh. J Forensic Med Sci Law. 2023; 32(2):14-9.
3. Shribhagwan, Singh M, Agarwal HS. Fingerprint pattern distribution in a cohort of Southeastern Haryana. J Forensic Med Sci Law. 2022; 31(2):4-10.
4. Patil SS, Deokar RB, Dongare SS. Prospective study of correlation of waist circumference with stature, weight and body mass index of the individuals. J Punjab Acad Forensic Med Toxicol.2023; 23(2): 119-28.
5. Acree MA, Is there a gender differentiation in fingerprint ridge density? Forensic Sci Int. 1999; 1102(1):35-44.
6. Ali F. I, Ahmed AA. Sexual and topological variability in palmprint ridge density in a sample of Sudanese population. Forensic Sci Int Rep. 2020; 2:100151.
7. Suthipraphal I, Riengrojpitak S, Tiensuwan M. Fingerprint ridge density and characteristics in Thais. Presented at: National Symposium; 2010; p.1–8.
8. Rivaldería N, Sánchez-Andrés Á, Alonso-Rodríguez C, Dipierri JE, Gutiérrez-Redomero E. Fingerprint ridge density in the Argentinean population and its application to sex inference: A comparative study. Homo. 2016; 67(1):65-84.
9. Kandel J, Ghimire, S., Bhandari R. Sex differentiation from fingerprint ridge Density. J Nobel Med Coll. 2023; 12(1), 13–6.
10. De Mesa RY, Yapchiongco YB, Evangelista CA, Alcantara MO, Kub-ao KD, Taduran RJ. Sex determination from plain fingerprint ridge density in Filipinos. Problemy kryminalistyki. 2021; 313(3):34-41.
11. Taduran RJO, Townsend GC, Tadeo AKV, Escalona NAC. Sex determination from fingerprint ridge density and white line counts in Filipinos. Homo.2016; 67(2):163-71.
12. Gungadin S. Sex Determination from Fingerprint Ridge Density. Internet J of Med Update. 2007; 2(2): 4-7.
13. Kumar L, Agarwal S, Garg R, Pratap A, Mishra VK. Gender determination using fingerprints in the region of Uttarakhand. J Indian Acad Forensic Med. 2013; 35(4): 308-11.
14. Sam MN, Rema P, Nair BV. Sex determination using fingerprint ridge density in South Indian population. J Indian Acad Forensic Med.2014; 36(4):381-6.
15. Kapoor N, Badiye A. Sex differences in the thumbprint ridge density in a central Indian population. Egyptian J Forensic Sci.2015; 5(1):23-9.
16. Sucharitha TM, Phanindra SV, Shaik A B, A study on sexual dimorphism in fingerprint ridge density among medical students of Nellore south coastal district of Andhra Pradesh. Indian J Clin Anat Physiol. 2021; 8(3):194-7.
17. Krishan K, Kanchan T, Ngangom C. A study of sex difference in fingerprint ridge density in a North Indian young adult population. J Forensic Leg Med. 2013; 20(4):217-22.
18. Garg P, Mustaria PS, Kumar N, Bansal MK, Yadav M. Analysis of Primary Fingerprint Patterns in Medical Students of Banda District Uttar Pradesh. J Forensic Med Sci Law 2022;31(1):28-32.
19. Sudhan MS, Raj HM, Kumar SV, Sowjanya D. Morphometric Analysis of Orbital Parameters for Sex Determination. J Forensic Med Sci Law 2023;32(2):39-42.
20. Ahmad N, Purkait R. Sex Estimation from the Shaft Fragment of Humerus Bone from Samples of Central Indian Skeletal Remains. J Forensic Med Sci Law 2021;30(2):4-9.
21. Chauhan A, Shukla SK. Feasibility of Ridge Density: A comparative study of fingerprint ridge densities among different Indian population. J Forensic Sci & Criminal Inves. 2017; 4(5):555654.