Sex Determination from Fingerprint Ridge Density

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ABSTRACT: This study was conducted with an aim to establish a relationship between sex and fingerprint ridge density. The fingerprints were taken from 500 subjects (250 males and 250 females) in the age group of 18-60 years. After taking fingerprints, the ridges were counted in the upper portion of the radial border of each print for all ten fingers and mean value was calculated. The results have shown that a finger print ridge of $\leq$ 13 ridges/25 mm^2 is more likely of male origin and finger print ridge of $\geq$ 14 ridges/25 mm^2 is more likely of female origin. It has been successful to support the hypothesis that women tend to have a statistically significant greater ridge density than men.

KEY WORDS: Fingerprint, Ridge density, Sex, Personal identification

INTRODUCTION:

Fingerprints of an individual have been used as one of the vital parts of identification in both civil and criminal cases because of their unique properties of absolute identity[1].

How the fingerprints slowly became standardized involves many persons, including Nathaniel Grew, Johannes Purkinje, William Herschel, Henry Faulds, Charles Darwin, Francis Galton, Mark Twain, Juan Vucetich, Edward Henry, and J. Edgar Hoover[2]. Since 700 AD, this science of fingerprint has been used for the purpose of identification[3]. Chinese used fingerprints as official documents in 3000BC[3]. The system was first used in India in 1858 by Sir William Herschel to prevent impersonation, but the credit is given to Sir Francis Galton for having it systematized for the identification of criminals. His system was officially adopted in England in 1894, and was further modified by Sir Edward Henry[3]. Afterwards the studies have been conducted on fingerprint ridges mainly its types, classification, methods of lifting fingerprints, recording of fingerprints and materials used to develop fingerprint.

Recently, many studies[4-7] have been carried out on the method of storing fingerprints in computers for rapid search and matching of fingerprints around the globe, but very few studies are available on this aspect. Therefore this study is planned to determine the sex from ridge density of fingerprints.

MATERIAL AND METHOD:

The study was conducted on 500 subjects (250 males and 250 females) in the year 2000-2002. In this study, the subjects were chosen randomly in the age group of 18-60 years from the state of Karnataka (Southern part of India). The materials used for this study were printers black ink, glass plate, roller, horseshoe lens, transparent film strip, pencil, measuring tape, bathroom scale, pin and Performa.

The subjects had been properly explained about the objectives of the intended study and consent had been taken. They were asked to wash and dry their hands to remove dirt and grease. For collection of fingerprint, a plain glass plate of about 12x12 inches had been cleaned and uniformly smeared with a thin layer of black printer ink by using the roller. After that the subject had been asked to apply their finger bulbs on the smeared plate and then transfer on the duly prepared fingerprint card, keeping in mind the need to minimize possible technical sources of dimensional artifact.

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The prints were taken with the fingers applied with regular pressure on the Performa. In this way for each and every individual the entire prints of ten fingers were prepared. Only plain prints were taken (no roll prints). The height and the weight of each subject were also recorded to know whether extremes of height and weight have had any impact over ridge density.

After taking fingerprints, the upper portion of the radial border of each print was chosen as an area for the data collection because all fingerprint pattern types showed a similar ridge flow in this region. In this region, the ridges conform to the finger outline flowing in an arch from one side of the finger to the other. The cores of loops and whorls pattern are away from this region. In this selected area of the prints, 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[8]. Counting started from one corner of the square to the diagonally opposite corner. Some specific criteria were observed during the counting procedure such as the dots, which were not counted, and the handle of the fork and a lake was counted as two ridges (though lakes were hardly seen). Hence this value represented the number of ridges/25 mm square and would reflect the ridge density value. The ridge thickness and the furrows are two important factors which determine the density of ridges. After the ridge counts were done for all the ten fingers, the mean value is calculated. This new value represented the approximate number of ridges for the particular individual. The significance of this value was determined.

Specific comparisons of means were made and calculations were performed using STATISTIX software on IBM computer. 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[9].

LR = Probability of given fingerprint originating from male contributor (C) / Probability of given fingerprint originating from female contributor (C^1)

RESULTS:

Table 1 shows that the males tend to have lesser number of ridges compared to females with a maximum of 13 ridges, where nearly 44% of males fall in this category. Beyond 13 ridges the number of males decreases rapidly and no male was found to have more than 15 ridges. On the other hand no female was found to have 11 ridges. The number of females with 15 ridges (54%) was very high as compared to males.

Table1: Sex wise distribution of epidermal ridges

No. of Ridges	Male		Female	
	No. of Cases	%	No. of Cases	%
11	16	6	-	-
12	80	32	5	2
13	110	44	20	8
14	35	14	65	26
15	10	4	135	54
16	-	-	25	10
Total	250		250	

Table 2 shows the descriptive statistics of epidermal ridges for male and female. The ridge density ranges from 11-15 ridges/25mm^2 in male and 12-16 ridges/25mm^2 in females. The analysis of variance (ANOVA) results show that males have significantly lesser density than females ($P<0.001$). The mean value of ridge count for male was 12.8 and that of female was 14.8.

Table 2: Descriptive Statistics of ridge density in both Males and Females

	Male	Female
Mean RC	12.8	14.6
SD	0.90	.085
SE	0.06	0.05
Minimum	11	12
Median	13	15
Maximum	15	16

Combined Mean 13.7±1.27, SE =0.06, t=23.49, P<.001

Table 3 shows the probability density for male (C) and female (C^1) and using these values, the likelihood ratio LR (C/C^1) and (C^1/C) were calculated. It is found that the LR is very high for the prints of 11 ridges because not a single female is found in this group. The LR value

tends to decrease till 13 ridges and when we see the other LR value (C^1/C) it is found that it increases drastically from 14 ridges onwards.

Table 3: Probability Densities and Likelihood Ratios derived from Observed Ridge Count

Ridge Count	Probability Density		Likelihood Ratio		Favored Odds	
	Male (C)	Female (C^1)	LR (C/C^1)	LR (C^1/C)	Males	Females
11	0.06	0.001	600.0	0.002	0.99	0.01
12	0.30	0.004	75.0	0.01	0.98	0.02
13	0.43	0.08	5.4	0.19	0.84	0.16
14	0.18	0.36	0.5	2.0	0.33	0.66
15	0.02	0.42	0.05	21.0	0.05	1.00
16	0.001	0.13	0.01	130.0	0.00	1.00

DISCUSSION:

Many studies have been conducted on ridge count but, mainly for race determination and genetic inheritance of ridge pattern. The present study has been conducted to broaden the horizon of ridge count i.e. sex determination by finger print ridge density. This study shows that males of Indian Origin in the Southern part of India do have significantly lesser ridge density as compared to females. It shows similar trends in sex difference as the other studies of the past conducted on other races. It also shows that this trend is universal among all races.

The statistical analysis of LR (C/C^1) and the favored odds show that a ridge count of $\leq$13 ridges/25mm^2 is more likely to be of male origin. Posterior probability using the Baye's theorem (P=0.84) and a ridge count of $\geq$14/25mm^2 is more likely to be of female origin (P=0.66). A print showing a count of $\leq$11 ridges/25 mm^2 will have a high probability to be that of male (P=0.99), while no female in this study was found to have 11 ridges. Similarly a ridge count of $\geq$16 ridges/25 mm^2 will be more in favor of female (P=1.0), while there was no male found in this category.

In the past many studies have been conducted on the finger print ridges with the idea of proving a gender difference in the finger print, but failed in the methodology. According to **Reddy**[10], the mean ridge count for males is 13.41 and that of female is 12.04. These figures were exactly the opposite of **Acree**[8]. A similar study was done on males and females of American Negroes and Caucasian American by **Plato et al**[11]. Here again they found the mean ridge density in male is more than female. These results could be due to some defect in the counting method as there is no detail of the counting method. **Cummins and Midlo**[12] have established proves that females do have higher mean ridge count (23.4) than males (20.7). These values are higher than the present study. This may be because the number of subjects studied is less and due to geographical variation. **Moore**[13] also carried out a study on ridge to ridge distance and found that mean distance is more in male compared to female, but he studied only 10 males and 10 females. **Okajima**[14] also found that fork index is higher in females than in male in fingerprints. This again upholds the trend as in this present study.

The results of this study have shown that males of Indian origin have a similar ridge density to the American females of Mark Acree's Study[8]. The females of Indian origin on an average have greater ridge density than the females of Acree's study. But the fact is that in both studies females within the population studies have significantly greater number of ridges than males. Studies conducted in the past have more or less given an insight about the difference in finger print ridge density, but none of them have been able to give an accurate method of measuring the density. This study has taken care of the details of the breadth and furrows of epidermal ridges and then statistically demonstrating the significant differences in male and female print density.

The results of the study are quite encouraging and this ultimately would be helpful as a useful tool for the fingerprint experts either in the field of Forensic Science or law enforcement field. In fact, the aim of taking the study was to help the authorities concerned to minimize or restrict their field of investigation and concentrate on a particular gender. This study has proved that there is an increased ridge density in female gender rather than male gender because of less coarseness of ridges. The study of sex identification by density is more specific and highly significant ($P > 0.001$). The studies conducted on Caucasian people and African people were also quite significant.

Limitations of study: This study is not 100% perfect/proof but certainly helps in identification of sex with most probability. Studies should be continued to fix the gender by 100% accuracy rather than "most probability". Another limitation is that these types of studies have not been carried out over Chinese, Japanese and Middle East people. If both these limitations are overcome then this sex identification by finger ridge density would have paramount value in crime investigation by saving precious time and giving them pertinent clue whether the finger print belongs to male or female individual.

CONCLUSION:

Identification by finger prints is infallible and now with the help of this study it will be further helpful to the fingerprint experts to direct their search to a particular gender and eventually the investigating officers would save time in nabbing suspects. The present study was conducted with an attempt to describe the densities of epidermal 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 show that a ridge count of $\leq$13 ridges/25 mm^2 is more likely to be of male origin and that of $\geq$14 ridges/25 mm^2 is likely to be of female origin.

The outcome of this study is that women have more ridge density than men. This would be universally accepted when these types of studies would be carried out in other parts of world.

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