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A Study on the Correlation of Gender with Fingerprint Ridge Density

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Abstract—

Fingerprint ridge density is an important quantitative dermatoglyphic parameter that has gained significant attention in forensic science, particularly for gender determination. The present study aims to examine the correlation between gender and fingerprint ridge density among individuals belonging to Tamil Nadu. A total of 100 fingerprint samples were collected, comprising 50 males and 50 females within the age group of 18–40 years. Fingerprint impressions of both thumbs were obtained using the standard ink method, and ridge density was calculated within a defined 5 × 5 mm² area located in the radial and ulnar regions of the fingerprint. The ridges were counted diagonally following established forensic protocols, and mean values were calculated for each individual. The results revealed a clear distinction in ridge density between genders, with females exhibiting a higher mean ridge density (13.815) compared to males (11.459). Statistical analysis demonstrated that ridge density is a consistent and reliable parameter for gender differentiation. However, the study also emphasizes that ridge density should be used in conjunction with other dermatoglyphic features for improved accuracy. The findings of this study reinforce the importance of fingerprint ridge density as a supportive tool in forensic identification and contribute to the growing body of research in forensic anthropology and biometrics.

Keywords— Fingerprint Ridge Density; Gender Determination; Dermatoglyphics; Forensic Identification; Ridge Analysis

I. INTRODUCTION

Fingerprints have long been recognized as one of the most reliable and widely accepted methods of personal identification in forensic science. Their uniqueness, permanence, and resistance to environmental changes make them an indispensable tool in both civil and criminal investigations.Fingerprint patterns are formed during fetal development and remain unchanged throughout an individual's lifetime, except in cases of severe injury.

Dermatoglyphics, the scientific study of fingerprint patterns and ridge characteristics, encompasses both qualitative and quantitative parameters. While qualitative aspects include pattern types such as arches, loops, and whorls, quantitative parameters involve ridge count and ridge density. Among these, ridge density has emerged as a significant indicator for determining biological attributes, particularly gender.

The concept of ridge density is based on the number of epidermal ridges present within a defined unit area. Previous research suggests that females generally possess narrower ridges, resulting in higher ridge density, whereas males exhibit broader ridges with lower density. This biological variation provides a potential basis for gender differentiation using fingerprint analysis.

Despite its significance, ridge density has not been explored as extensively as other fingerprint parameters such as pattern type and minutiae characteristics. Therefore, the present study aims to investigate the correlation between gender and fingerprint ridge density within a specific population and evaluate its applicability in forensic identification.

Objectives of the Study:

1. To determine the fingerprint ridge density in male and female individuals
2. To compare ridge density values between genders
3. To assess the reliability of ridge density in gender determination

II. LITERATURE REVIEW

Fingerprint ridge density has been extensively studied as a quantitative parameter for gender determination in forensic science. Several researchers have contributed to understanding its significance across different populations.

Gungadin (2007) conducted a pioneering study involving 500 participants and established that females generally exhibit higher ridge density than males. The study provided statistical thresholds indicating that ridge counts below 13 per unit area are more likely to belong to males, while counts above 14 are indicative of females .

Nagurka et al. (2008) emphasized that ridge density alone may not always be sufficient for gender classification and suggested combining it with other biometric parameters such as finger size and ridge count. Similarly, Bhardwaj et al. (2014) found no significant gender differences in loop ridge count, highlighting the importance of focusing on ridge density as a more reliable indicator.

Advancements in computational analysis have further enhanced fingerprint-based gender identification. Kaur et al. (2012) utilized frequency domain techniques such as FFT and DCT to improve classification accuracy. Agarwal et al. (2014) reviewed multiple fingerprint-based gender classification methods and identified ridge density as a key parameter.

Soanboon et al. (2015) and Oktem et al. (2015) conducted population-based studies and confirmed that females consistently exhibit higher ridge density across different anatomical regions. Their findings support the concept of sexual dimorphism in fingerprint characteristics.

Recent studies incorporating artificial intelligence, such as those by Jayakala et al. (2021) and Spanier et al. (2024), demonstrate that combining ridge density with machine learning techniques significantly improves classification accuracy.

Despite these advancements, researchers emphasize that ridge density should be used alongside other forensic parameters due to potential variations caused by environmental and genetic factors. The present study builds upon existing literature by analyzing ridge density variations in a Tamil Nadu population.

III. METHODOLOGY

A. Study Design and Sample Collection

The study was conducted using an experimental approach. Fingerprint samples were collected from 100 healthy individuals aged between 18 and 40 years, comprising 50 males and 50 females. Individuals with skin diseases, burns, or deformities affecting fingerprints were excluded to ensure accuracy .

B. Materials Used

1. Ink pad
2. A4 sheets
3. Magnifying glass
4. Measuring scale

C. Procedure

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Participants were instructed to wash and dry their hands prior to fingerprint collection. Ink was applied evenly on the thumb, and impressions were taken on white paper using the rolling method. Both left and right thumb impressions were recorded.

For ridge density analysis, a square area of 5 × 5 mm² was selected near the central core in both radial and ulnar regions. Ridges within this area were counted diagonally. Special care was taken to ensure consistency in measurement.

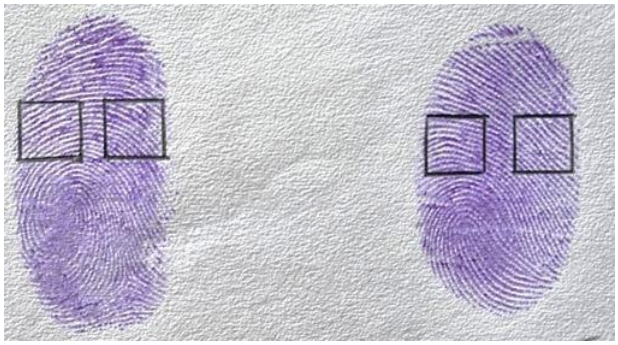

Figure 3.1 Right (R) and left (L) thumb impressions from a male sample.

Figure 3.2 Right (R) and left (L) thumb impressions from a female sample

D. Data Analysis

The ridge counts from both hands were averaged to obtain a single value for each individual. Mean ridge density values were calculated separately for male and female groups. Statistical comparison was performed to evaluate differences between genders.

IV. RESULTS AND DISCUSSION

The results of the study clearly demonstrate a significant variation in fingerprint ridge density between males and females.

Mean ridge density (Male): **11.459**

Mean ridge density (Female): **13.815**

Table I: Ridge Density Comparison

Gender	Sample Size	Mean	Standard Deviation	Range
Male	50	11.459	1.58	9.75–15.75
Female	50	13.815	1.38	11–16.25

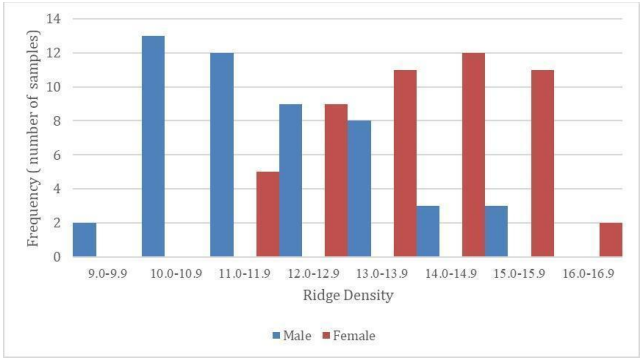

Figure 4.1 Comparative frequency distribution of fingerprint ridge density in males and females

The results indicate that females consistently exhibit higher ridge density than males. This finding aligns with previous studies and supports the hypothesis that ridge density can serve as a reliable indicator of gender.

The frequency distribution graph (Figure 4.1) shows a clear separation between male and female ridge density ranges, with males clustering in lower density ranges and females in higher ranges.

The observed differences can be attributed to biological variations, where females typically have narrower epidermal ridges compared to males. However, minor variations may occur due to environmental and genetic factors.

V. CONCLUSION

The present study confirms that fingerprint ridge density is a significant parameter for gender differentiation in forensic investigations. Females exhibit higher ridge density values compared to males, making it a useful tool for preliminary gender identification.

However, ridge density should not be considered a standalone parameter. Its effectiveness increases when used in combination with other dermatoglyphic features such as pattern type, ridge count, and minutiae analysis.

The findings contribute to the existing body of forensic knowledge and highlight the importance of dermatoglyphics in personal identification and criminal investigations.

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