

Determination of Sex and Hand from Individual Fingerprints

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Abstract

A fingerprint found at the crime scene is one of the most crucial fragments of personal identification that a person might leave behind. Apart from being every person's unique identification mark that are ubiquitous to all, to start with, they often reveal on further examination, certain characteristics about the person that might narrow down the suspects' pool. To identify criterions that can be conclusively analyzed to determine the side of hand and sex of a person from the fingerprint, bilateral rolled fingerprints of 200 individuals were studied. To overcome the aspect of geographical deviation, samples were collected from four major ethno-linguist populations of various regions of India namely Punjab, Tamil Nadu, West Bengal and Rajasthan. Prevalence of different patterns in different regions and between males and females was studied. Determination of sex from Average Ridge Count and Average Ridge Width was assessed. Both of the above parameters were found to be significantly higher in males as compared to females. In all the fingerprint patterns except plain arches, Core-Delta Euclidean Distance and the consequent slope was measured and the side of hand determined. The Right Hand Sides of both males and females have significantly lower Core Delta Euclidean Distance and higher slope angle as compared to their Left Hand Sides. All the parameters were measured through FACTS (Fingerprint Analysis and Criminal Tracing System) which is an AFIS (Automated Fingerprint Identification System). The findings of this study are helpful in concluding both the hand side and sex by analyzing an individual fingerprint.

Keywords: Fingerprints; Hand determination; Sex determination

Introduction

Human fingerprints are unique, impressively detailed, not easily altered and are permanent to a person throughout life and hence serve as life-long markers of one's identity. Fingerprinting is one of the many branches of biometrics- the science of using one's physical characteristics or traits to identify them. Fingerprints are a model form of biometrics due to their permanency as

well as hassle free and inexpensive collection and analysis. In order to make a positive identification on the basis of fingerprints, one is ought to follow the scientific procedure of ACE-V which stands for Analysis, Comparison, Evaluation and Verification respectively [1]. The levels of details in fingerprints are simple descriptions of the different types of information present throughout the print. Various levels are detectable depending upon the clarity of the fingerprint impression. Level 1 details are the general directional ridge flow but

not limited to a defined classification pattern. Galton details or Level 2 detail is the path taken by a specific ridge. This includes the path taken by the ridge, the length of the path traversed and where the ridge path stops. It is much more than the specific location at which a ridge terminates or its Galton points. Sequences as well as configurations with other ridge patterns are critical elements of Level 2 details. Level 3 details deal with the shapes of the ridge structures. This encompasses the morphology of the edges or Edgescopy, textures as well as the pore positions of the ridges. Core and Delta are the focal points when it comes to identifying the pattern in a fingerprint or even delineating minutiae proportions and positions relatively [2]. This is due to the fact that these points are present in all fingerprint patterns except for plain arches and hence prove to be a valuable yardstick.

Various parameters that are present in the Core-Delta region give away personal characteristics of a person on further analysis. Minutiae to Ridge Length Ratio or MRLR are one such criteria which shows significant variation across sex, race as well as finger determination. MRLR also shows sex difference associated with finger and fingerprint pattern. Studies have shown significant variation in MRLR across the five fingers except ring and little finger [3]. Dexterity or handedness i.e. the predominantly used hand in day to day life, is determined before one's birth and has a genetic component to play a great role. Left Handed people tend to have significantly higher incidence of Central pocket loops, S-shaped loops, arches, radial loops as well as certain minutiae combinations.

Minutiae are not just benchmarks for identification but also reveal other features. Minutiae specifically bifurcations and ridge endings which are the two most common ridge characteristics, vary specifically among patterns. Total bifurcations have been promising in revealing the race of a person [4].

Often during court proceedings or crime scene recreation or otherwise during the course of investigation, it assumes vital importance to determine as to which side of hand the questioned fingerprint originated from. It becomes of crucial value when the fingerprint is incomplete hence making traditional fingerprint matching futile. On the other hand, determination of sex excludes half the population from the list of suspects and might even give a no suspect case a possible lead. Ohler and Cummins have found in their study that the epidermal ridge breadth in males is significantly higher than in females [5]. Singh, et al. [5] have studied bilateral rolled fingerprints of Punjabi Jat males and shown that whorl patterns are useful in left

and right hand determination. Nagesh, et al. [6] have studied bilateral rolled fingerprints of South Indian males and females and shown that whorl patterns can be used in hand determination [6]. In the present study, an attempt has been made to determine the hand by using all fingerprint patterns except tented arches, i.e. loops, whorls and plain arches and compare the results with the previous studies. To take into consideration the regional deviation in fingerprint characteristics, rolled fingerprints have been collected from Punjab, Tamil Nadu, West Bengal and Rajasthan in order to get a comparative as well as holistic perspective.

Material and Methods

Fingerprints

The original 2000 fingerprints were collected by the Central Fingerprint Bureau and were previously scanned at 1200 ppi to be used as subjects in this research. Only demographic information (native state, gender and age) was provided to the researcher for each individual. The subject population comprised equal subsets of both Males and Females from four states: Punjab, Tamil Nadu, West Bengal and Rajasthan. Each of these categories had 25 male and 25 female ten-rolled-fingerprint cards. All the subjects were aged 18-70 year old. Each fingerprint was assigned an identifier to correspond with the sex, native state and finger. This is composed of a primary alphabet that relays the sex (M/F), followed by a secondary alphabet denoting the cardinal direction in which the native state lies w.r.t. India (E/W/N/S), a primary number denoting the individual and lastly a secondary number that details the finger from which the print originated. The fingers are numbered starting from the Right Hand and then the Left Hand in the following order:

Right Hand Rolled Prints					Left Hand Rolled Prints				
T	I	M	R	L	T	I	M	R	L
1	2	3	4	5	6	7	8	9	10

Table 1: Numbering of fingers in both hands.

An example would be M_E_01_4, the right ring finger of a Male from West Bengal. The guidelines provided by the Federal Bureau of Investigation were followed using standard ten-print cards. Individual rolled fingerprint impressions were collected along with simultaneous impressions, wherein all four fingers are inked and then stamped at the same time, along with another thumbprint impression. To ensure high quality images, the impressions were then scanned at 1200 ppi³⁷ using an Epson® Perfection® 1650 flatbed scanner (Seiko Epson Corporation, Suwa, Nagano, Japan).

Analysis

The analyses of the fingerprint impressions were carried out on an HP Pavilion p7-1154 PC using the software FACTS (Fingerprint Analysis and Criminal

Tracing System) which is an AFIS (Automated Fingerprint Identification System). Core and Delta points were pin pointed via FACTS and cross checked by the researcher.

Pattern Type	No. of Cores	No. of Deltas	Position
Radial Loop	1	1	Delta is on left of Core in right hand and vice versa.
Ulnar Loop	1	1	Delta is on right of Core in right hand and vice versa.
Plain Arch	-	-	-
Tented Arch	1	1	Delta lies below the core
Whorls	1 or more	2	Varies
S-shaped	2	2	Outwards
C-Pocket		2	Below

Table 2: Core-Delta position in patterns.

Fingerprint Pattern Distribution Analysis

All the finger prints were categorized into Ulnar & Radial Loops, Plain & Tented Arches and Whorls by FACTS and cross checked by the researcher.

Total Ridge Count

As opposed to the traditional procedure of counting the number of ridges from delta to core, in this work the total ridge count is measured by drawing an imaginary line from core to delta and two other, one at 135 degree (principal diagonal) and other at 45 degree (other diagonal) upwards from the core point. The frequency of white pixels along any line of interest denotes the ridge count along that line. Ridge Count is measured along the 3 imaginary lines and labelled as follows (Figure 1):

- a: core to delta ridge count
- b: principal diagonal ridge count
- c: other diagonal ridge count

The Total Ridge Count is calculated as:

$$TRC = a + \frac{1}{2}(b+c)$$

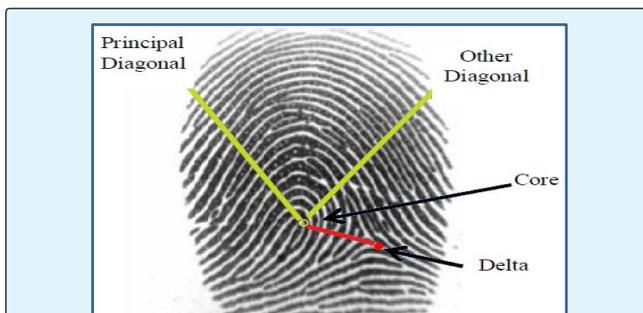


Figure 1: Total Ridge Count.

Ridge Width

Additionally, two lines are drawn across core and delta points along with the aforementioned criterions. Along the line of interest, the number of black pixels divided by the ridge count denotes the average ridge width (Figure 2).

- A: average ridge width from core to delta
- B: average ridge width in principal diagonal
- C: average ridge width in other diagonal
- D: horizontal line across core
- E: horizontal line across delta

Along the line, Average Ridge Width = Number of black pixels / Ridge Count

Ridge Width is calculated by:
 $RW = \frac{A+B+C+D+E}{5}$ (in micrometers)

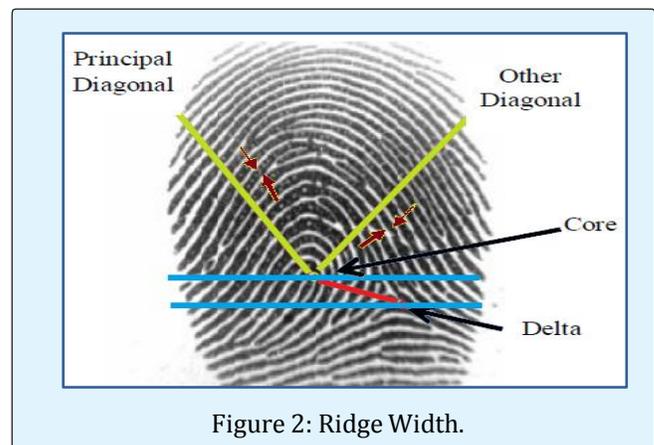


Figure 2: Ridge Width.

Core-Delta Euclidean Distance

Core and Delta co-ordinates are measured via FACTS and C-D distance is calculated by the following equation:

$$\text{Euclidean distance} = \sqrt{(C_x - D_x)^2 + (C_y - D_y)^2}$$

Core-Delta Slope Angle

The slope angle from Delta w.r.t. Core is calculated using the two point slope formula:

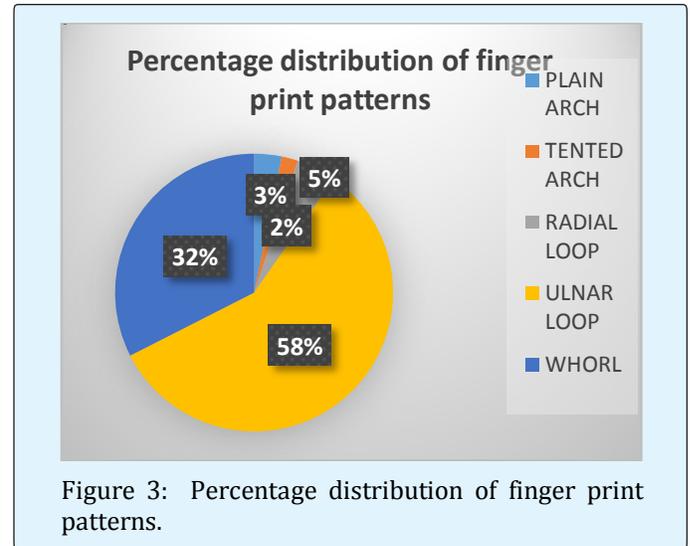
$$\text{Slope} = (D_y - C_y) / (D_x - C_x)$$

Core-Delta angle = $\tan^{-1}(\text{slope})$

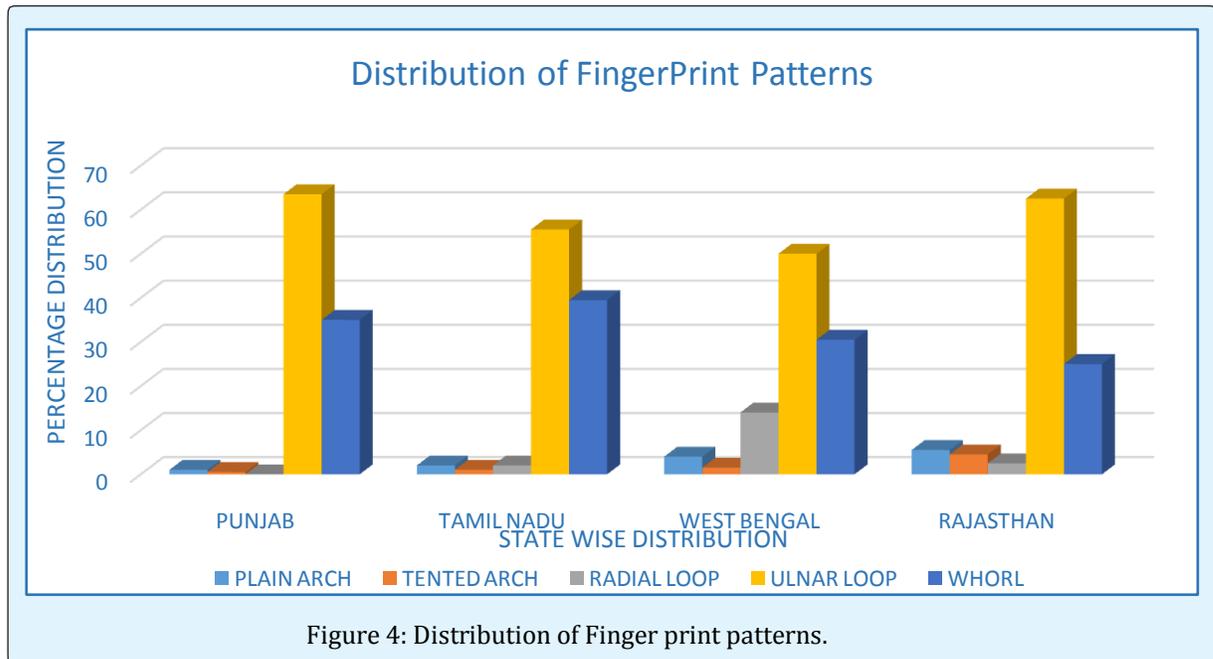
Results

Fingerprint Pattern Statistics

Percentage distribution of most common fingerprint patterns: The most frequently occurring patterns are the Ulnar Loops followed by Whorls which is consistent with other studies such as that of Banik SD et al. The occurrence of Arches is almost as much as that of Radial Loops with Tented Arches being the least common (Figure 3).



The prevalence of fingerprints of various patterns has been studied in Punjab, Tamil Nadu, West Bengal and Rajasthan: In all the regions, the Ulnar Loops are the most prevalent. Whorls are the second most prevalent finger print patterns in all regions except in Rajasthan where their occurrence is negligible. The occurrence of Radial Loops is highest in the West Bengal and lowest in Punjab. The occurrence of patterns varies significantly from region to region across India (Figure 4).



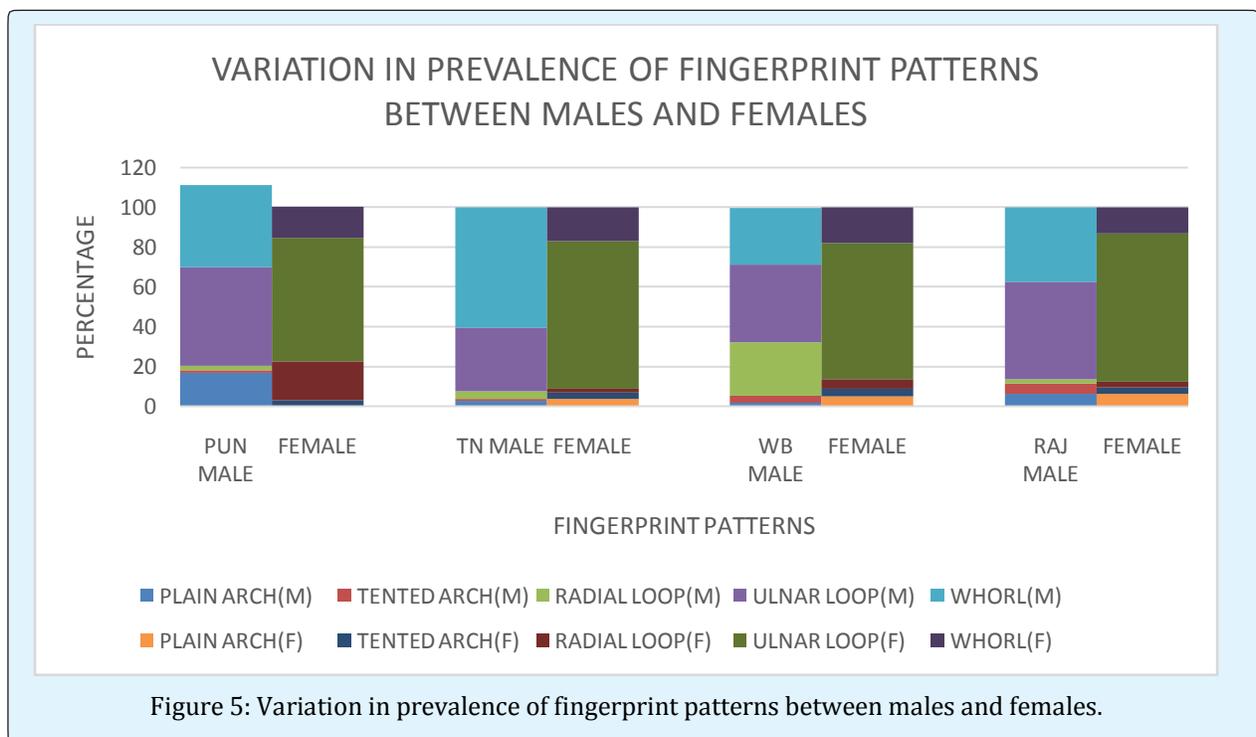
Variation in prevalence of fingerprints between Males and Females: Punjab: Ulnar Loops are the most prevalent finger print patterns in both males and females. Whorl are almost negligible in females but second most prevalent in males. Plain Arches are significantly more prevalent in males than females.

Tamil Nadu: The most prevalent finger print patterns in males and females are Whorls and Ulnar Loops respectively.

West Bengal: Ulnar Loops are the predominant finger print patterns in both males and females but are present to a higher degree in females. The frequency of Radial Loops and Whorls is much more in males.

Rajasthan: Ulnar Loops are the predominant finger print pattern but the prevalence is significantly more in females. Whorls are the second most prevalent finger print patterns in males but almost negligible in females. Radial Loops are the rarest finger print patterns.

General Trend: Ulnar Loops are the predominant finger print patterns in both males and females but constitute a greater portion in females as compared to males. Whorls are the second most predominant finger print patterns in both males and females but constitute a significantly greater portion in males as compared to females. Tented Arches are the least observed finger print patterns in both males and females (Figure 5).



Determination of Sex from Total Ridge Count and Ridge Width

Variation in Ridge Count between males and females:

Punjab: The Ridge Count in Females ranges from 15-28 and from 30-45 in Males. The variation in ridge count is more abrupt across the fingers in females as compared to in males. The ridge count is highest in the thumb [M: 44 F: 26] and lowest in the little finger [M: 33 F: 16] in both sexes.

Tamil Nadu: The Ridge Count in Females ranges from 25-30 in Females and from 30-40 in Males. The thumb [M: 40

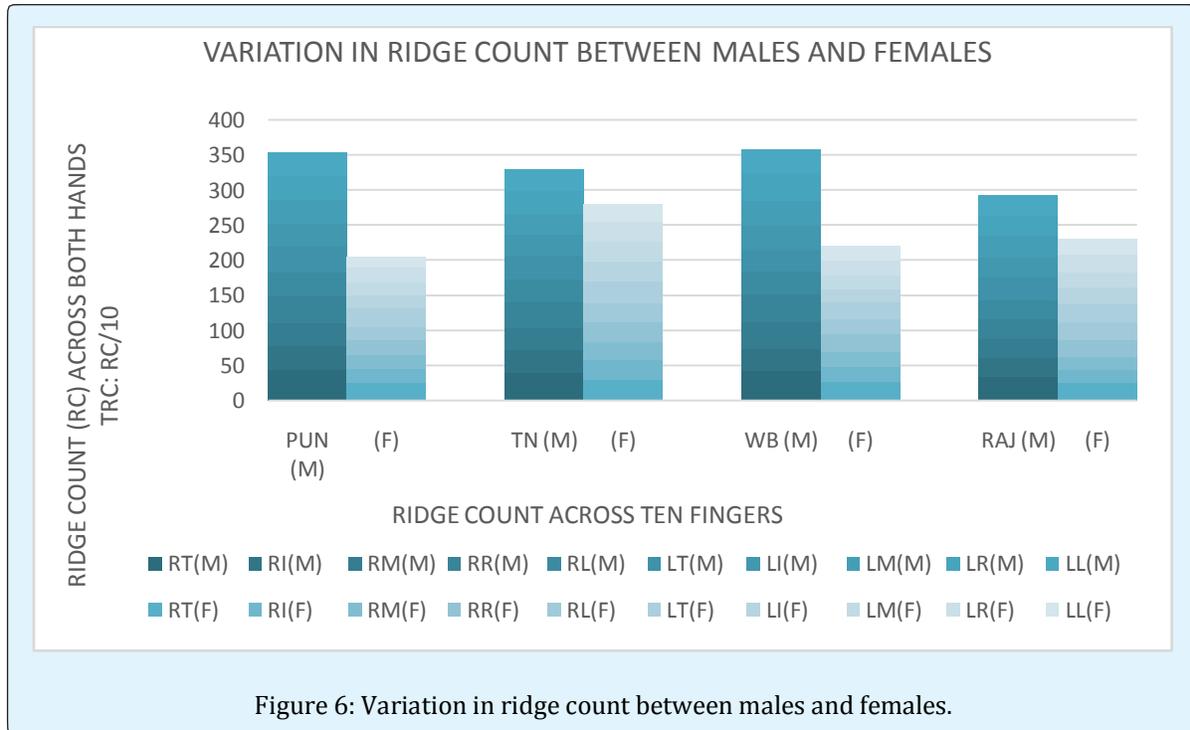
F: 30] has the highest ridge count whereas the little finger [M: 30 F: 26] has the lowest ridge count in both males as well as females.

West Bengal: The Ridge Count in Females ranges from 18-28 while it ranges from 30-42 in Males. Ridge Count also varies across different fingers in an individual. The thumb [M: 42 F: 28] and the ring finger [M: 42 F: 25] have the highest ridge count while the index [M: 31 F: 20] and the little finger [M: 32 F: 20] have the lowest ridge counts in both males and females.

Rajasthan: The Ridge Count in Females ranges from 18-26 and from 26-35 in Males. The thumb [M: 33 F: 26] has the highest ridge count whereas the little finger [M: 29 F: 23] has the lowest ridge count in both males as well as females.

General Trend: The ridge count varies significantly across both females and males. The ridge count is higher

in males [>30] and lower in females [20-30]. Also, it is observed that the ridge count is generally highest in thumb and lowest in the index finger and little finger. Ridge count is highest in Punjabi males and lowest in Rajasthani males. Ridge count is highest in females from TN and lowest in Punjabi females (Figure 6).



Variation in terms of Ridge Width between males and females: West Bengal: The Ridge Width in Females ranges from 300-470 μm while it ranges above from 500-550 μm . The Ridge Width is higher in Thumb [M: 560 μm F: 470 μm] and lower in the little finger [M: 500 μm F: 320 μm].

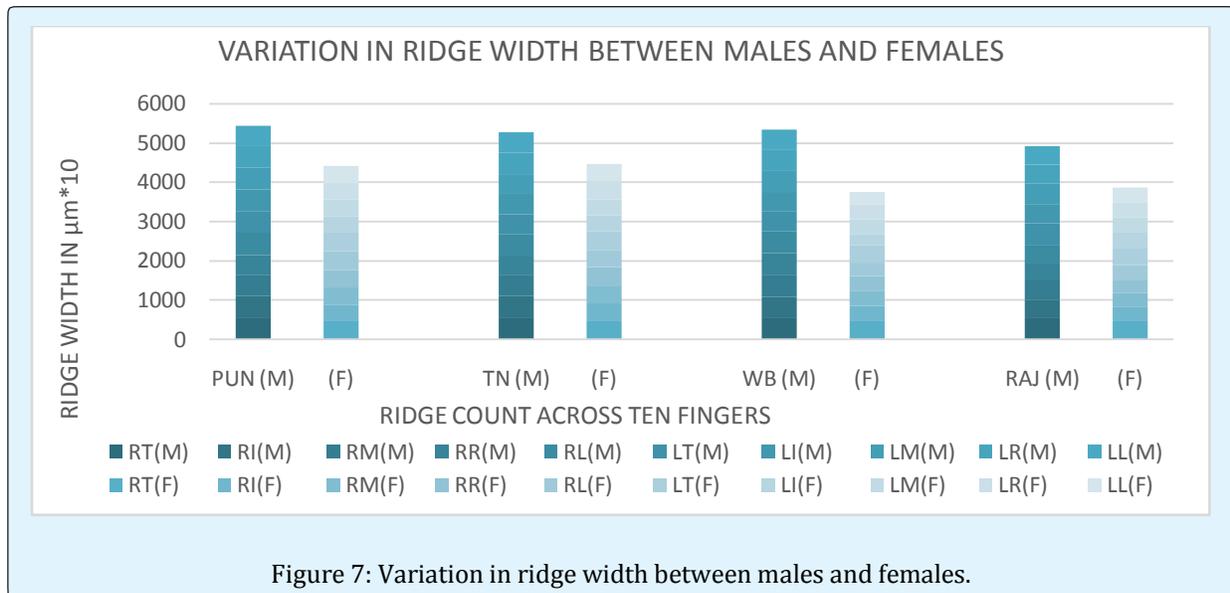
Rajasthan: The Ridge Width in Females ranges from 330-470 μm and from 470-560 in Males. The Ridge Width is highest in Thumb [M: 560 μm F: 470 μm] and lower in both little [M: 480 μm F: 390 μm] and index fingers [M: 450 μm F: 350 μm].

Punjab: The Ridge Width in Females ranges from 420-470 μm and from 500-560 μm in males. The Ridge Width

is higher in Thumb [M: 560 μm F: 470 μm] whereas it is lower in the little finger [M: 510 μm F: 430 μm].

Tamil Nadu: The Ridge Width in Females ranges from 400-470 μm and from 500-560 μm in Males. The Ring Finger has smaller width [M: 500 μm F: 470 μm] and Thumb [M: 560 μm F: 470 μm] has the widest ridges.

General Trend: There is a significant difference in Ridge Width between Males and Females. The Ridge Width in Females ranges from 400-500 μm and above 500 μm in Males. The Ridge Width variation becomes significant in the age group 19-25 unlike earlier age groups. Age also causes Ridge Width to be stretched. The ridge width is highest in the males from Punjab and Tamil Nadu and lowest in the females from West Bengal (Figure 7).



Determination of Hand from Core-Delta Euclidean Distance and Slope Angle

Variation of Core-Delta Euclidean Distance across both Hands: West Bengal: The Core-Delta Euclidean Distance ranges from 4.6-5.3 mm in Left Hand and from 3.2-4.1 mm in the Right Hand for both Males and Females. The C-D Euclidean Distance is lowest for Thumb [LHS: 4.6 mm RHS: 3.2 mm] and considerably higher for Little fingers [LHS: 5.1 mm RHS: 3.7 mm].

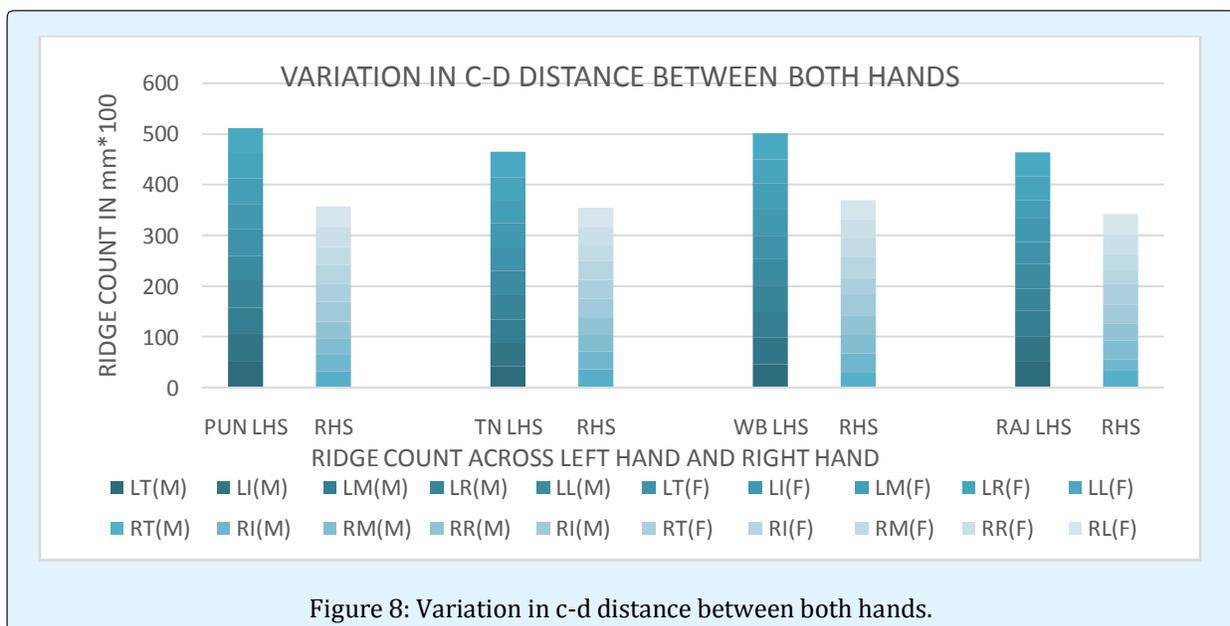
Rajasthan: The C-D Euclidean Distance ranges from 3.6-5.2 mm in Left Hand and from 2.3-3.6 mm in Right Hand. The C-D Euclidean Distance is lowest for Thumb [LHS: 5.2

mm RHS: 3.4 mm] and considerably higher for Little fingers [LHS: 4.7 mm RHS: 4 mm].

Punjab: The C-D Euclidean Distance ranges from 4.8-5.2 mm in Left Hand and from 3.0-4.0 mm in Right Hand. The Thumb [LHS: 5.2 mm RHS: 3.3 mm] generally has a low C-D Euclidean Distance.

Tamil Nadu: The C-D Euclidean Distance ranges from 4.3-5.0 mm in Left Hand and from 3.2-3.8 mm in Right Hand.

General Trend: The C-D Euclidean Distance is significantly higher in the Left Hand [4.5-5.5 mm] and lower in the Right Hand [3-4 mm] (Figure 8).



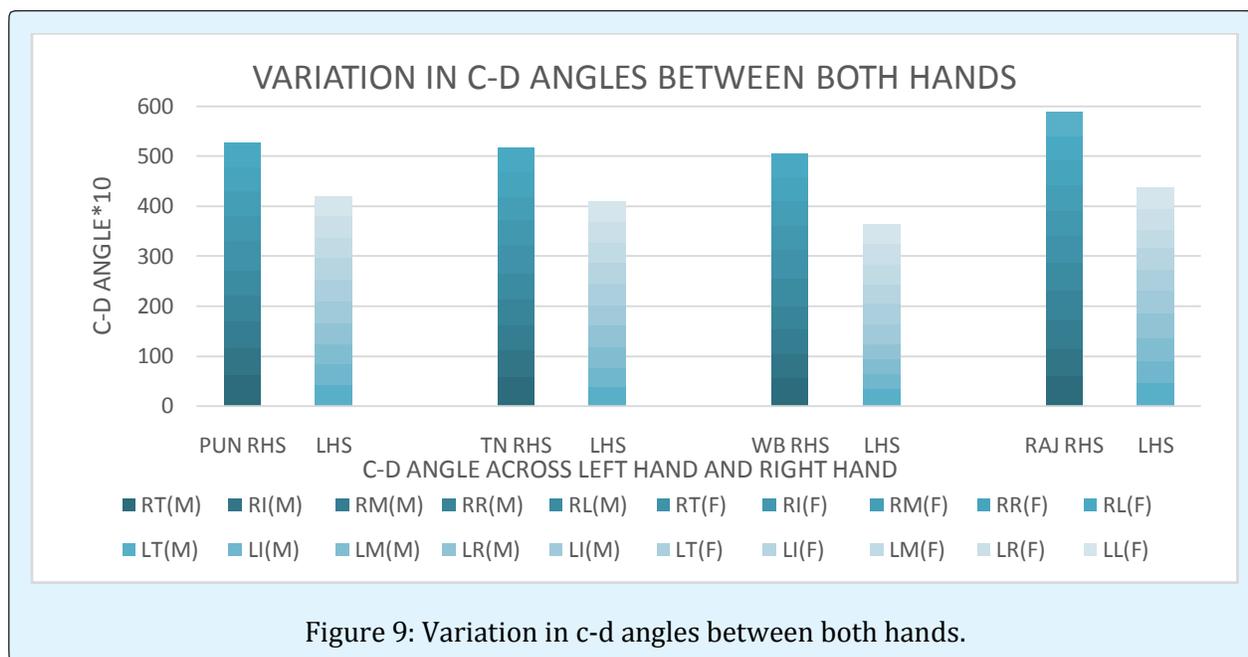
Variation in slope values across various regions of India in both hands: West Bengal: The C-D Euclidean angle is higher in the right hand [45°-60°] and lower in the left hand [28°-43°]. Also, it has been observed that the C-D Euclidean Distance is high in thumb in both the hands.

Rajasthan: The C-D Euclidean angle is higher in the right hand [46°-62°] and lowers in the left hand [38°-45°]. The C-D Euclidean Distance is high in thumb in both the hands.

Punjab: The C-D Euclidean angle is higher in the right hand [48°-62°] and lowers in the left hand [43°-39°]. Also,

it has been observed that the C-D Euclidean Distance is high in thumb in both the hands.

Tamil Nadu: The C-D Euclidean angle is higher in the right hand [47°-58°] and lowers in the left hand [39°-43°]. The Core-Delta Euclidean angles differ significantly between both Hands, the Right Hand having a higher slope angle. The Slope Value in Right Hand is above 46° and lower than 46° for the Left Hand. The C-D Euclidean angle is highest in the right hand of Punjabis and lowest in the left hands of Bengalis. Also, the variation in Slope Angle among fingers is higher in the Right Hand and considerably gradual in the Left Hand (Figure 9).



Discussion

In the present study, 2000 rolled fingerprints from 200 individuals were analyzed. The Ulnar Loops are observed to be the most predominant fingerprint patterns followed by whorls in both left and right hands, which is consistent with other studies [4,5,7]. However, the findings differ from the study by Banik SD et al. in which whorls were the most predominant finger print patterns followed by the loops [7]. The direction of Core Delta Slope in both hands was consistent with the study of Singh, et al. [5] and Nagesh, et al. [6]. The difference in Ridge characteristics in terms of ridge count and ridge width between males and females is consistent with the study of Ohler and Cummins with the ridge count being higher and the ridge width being wider in the males [8].

Conclusion

An analysis was done to determine the hand and sex from a fingerprint in ethno-linguist Indian population from Punjab, Tamil Nadu, West Bengal and Rajasthan and the results were studied.

The salient features of the study include:

- Predominance of Ulnar Loops was observed across all regions. Whorls are more predominant in Females and arches are the least observed pattern.
- Males have a higher Ridge Count as well as wider ridges.
- The Ridge Count in Females ranges from 20-30 and is above 30 in Males.

- The Ridge Width in Females ranges from 400-500 μm but is greater than 500 μm in Males.
 - The Right Hands of both Males and Females have significantly lower C-D Euclidean Distance and higher Slope values as compared to their Left Hands.
 - The Slope Value in Right Hand is above 46° and lower than 46° for the Left Hand.
 - The findings of this study are helpful in concluding both the Hand and the Sex from which the fingerprint originated by analyzing an individual fingerprint.
 - Limitation: Not applicable for Plain Arches.
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Conflict of Interest

None declared.

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