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Exploring the Potential of Ridge Density as a Measure of Sex Identification

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Abstract

Identification of individual based on fingerprints is well established and widely used for both security and forensic purposes. In a forensic scenario, when a fingerprint is found at a scene of crime, it is sought to compare with the fingerprints from a set of suspects. Sex Identification may be considered as first level of identification. In this study, potential of ridge density has been explored for sex identification within wide age groups. A database of fingerprints collected from 190(95 Male and 95 Female) people of various age groups ranging from 1-70 year from Marathwada population has been prepared. Analysis of the fingerprints shows ridge density as an efficient sex marker except for the kids less than 10 years of age. The present study was aimed to explore the potential of ridge density in sex identification. The variability due to well defined area for the calculation of ridge density was also explored. The study revealed that there is no significant difference in ridge density due to selected region. As far as variability due to age is concerned, it has been found that there is stability in ridge density once the age crosses 10 years. As far as identification of sex is concerned, there is a difference of 1-2 ridges when ridge density of male vs. female is calculated, which may be due to average over a small database.

Keywords: Ridge density • Sex difference • Fingerprint • Forensic science

Introduction

Fingerprint is one of the trusted means of person identification. Researchers have carried out numerous works in the domain of fingerprints varying from pattern identification to person identification. There are many features which have been studied in fingerprints (ridge count, ridge orientation etc.) in relation to various factors of human population. Sex is one such factor. Ridge width influences the number of ridges presents in a specified area of fingerprints i.e., the epidermal ridge density.

Epidermal ridges and their arrangement are formed very early in embryonic development, and from the 26th week of gestation the dermatoglyphic patterns retain their configuration essentially unchanged during the lifetime of an individual and even after death if the tissues are preserved. However, although the number of ridges is independent of age, their size will increase to accommodate the overall growth of the body, particularly on the hands and feet, until adult size is reached.

From last several decades fingerprints are being used for determining the individual identification. But this is only possible when we get whole fingerprint pattern. Not always we get whole fingerprint pattern from crime scene. Sometime we only get partial print and this doesn't allow us to determine individual identity. In that case at least we can go for gender identification by calculating fingerprint ridge density. And this will help to narrow down the investigation area.

Although, there has already been much research on the differences between sexes in fingerprint ridge density and its variability in Indian population. Such studies have not included people from Marathwada region aged between 1 to 10 years. And also such studies have not explained about which area of fingerprint should be selected for calculating ridge density. And also such studies have not included different age groups in a one study. In this study, potential of ridge density will be explored for sex identification within wide age groups ranging from 1 to 70 years for different topological areas.

Literature Review

Mark Acree in 1999 conducted a study to determine if women have significantly higher ridge density, hence finer epidermal ridge detail, than men by counting ridges that occur within a well-defined space. The study focused on 400 randomly picked ten-print cards representing 400 subjects. The demographic composition of this sample population represented 100 Caucasian males, 100 African American males, 100 Caucasian females and 100 African American females all within the age range of 16-67. Results showed that women tend to have a significantly higher ridge density than men and that this trend is upheld in subjects of both Caucasian and African American descent ($F = 61.96$, $P < 0.001$). Application of Bayes' theorem suggested that a given fingerprint possessing a ridge density of 11 ridges/25 mm^2 or less is most likely to be of male origin. Likewise a fingerprint having a ridge density of 12 ridges/25 mm^2 or greater is most likely to be of female origin, regardless of race [1].

Gungadin in 2007 conducted study 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 <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 [2].

A study was undertaken by Nayak in 2009 to understand the sex differences in fingerprint ridge density in the Indian population. The study done on 100 males and 100 females revealed that significant sex

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differences occur in the fingerprint ridge density. A mean fingerprint ridge density of 12 ridges/25 mm^2 or less is found to be more likely to be of males and a mean ridge count of more the 12 ridges/25 mm^2 is more likely to be of female origin [3].

The study was undertaken by Nayak in 2009 to study the gender differences in fingerprint ridge density in Chinese and Malaysian population. The study done on 200 subjects (100 males and 100 females) of Chinese origin and 100 subjects (50 males and 50 females) of Malaysian origin revealed that significant gender differences occur in the finger ridge density. Fingerprint mean ridge density of 12 ridges/25 mm^2 or less is found to be more likely to be of males and a mean ridge count of more the 13 ridges/25 mm^2 is more likely of female origin in Chinese subjects. Fingerprint mean ridge density of 11 ridges/25 mm^2 or less is found to be more likely to be of males and a mean ridge count of more the 13 ridges/25 mm^2 is more likely of female origin in Malaysian subjects [4].

Nithin Mandya in 2011 conducted study to determine the gender based on finger ridge count within a well-defined area. Rolled fingerprints were taken from 550 subjects (275 men and 275 women) belonging to South Indian population all within the age range of 18-65 years. Results have shown that women have a significantly higher ridge count than men. Application of Baye's theorem suggests that a fingerprint possessing ridge density <13 ridges/25 mm^2 is most likely to be of male origin. Likewise, a fingerprint having ridge count >14 ridges/25 mm^2 are most likely to be of female origin [5].

Gagandeep Singh carried out research with an aim to examine ridge density differences in two Northern Indian populations (Khatri and Bania). In this study it has been found that 92% of Khatri females have a mean ridge density above 13, whereas 76% of Khatri males have (a mean ridge density) below 13, while in Bania, 100% of females have mean ridge density above 14 and 80% of males below 14. The study suggests that there are significant differences in epidermal ridge density between males and females within each of the two populations and also significant differences between the two populations [6].

Ghada Eshak conducted study on 752 healthy adult Egyptian subjects (380 males and 372 females) with age ranged from 20 to 30 years. Consents were obtained from all participants and their 10 digits were photographed to determine the sexual dimorphism by some fingertip features (ridge count, square area, finger breadth and finally ridge density) in Egyptians. Statistical analysis was made using a multivariate logistic regression variation analyses. Results showed that females tend to have statistically significant shorter (narrower) finger breadth (right: male>9.54 female; left: male>9.38 female), smaller square area (right: male 16.1 > female, left: male > 15.1 female), more ridge count (right: female > 21.0 male, left: female > 21.2 male), and higher ridge density (right: female >1.35 male, left: female > 1.5 male) when compared with males. The ridge density of the left hand was the most single accurate parameter in correct sex determination. The best classification accuracy of 82% was generated upon combining ridge count, square area and ridge density [7].

Kewal Krishan conducted a research to distinguish sex from fingerprint ridge density in the radial, ulnar and lower areas of a fingerprint in a North Indian population. A total of 194 individuals (97 males and 97 females) aged between 18 and 25 years were included in the study and fingerprints were collected from each finger of the participants. Thus, a total of 1940 fingerprints were obtained and epidermal ridges were counted in the radial, ulnar, and lower areas of each fingerprint. The radial and ulnar areas are the 5 mm × 5 mm areas on the radial and ulnar side of the central core respectively while the lower area is designated as 5 mm × 5 mm area adjoining the flexion crease of the terminal phalanx on a fingerprint. The fingerprint ridge density in radial, ulnar and lower areas and between sexes was compared statistically using t-test. The results indicate that the females tend to have a significantly higher ridge density than males in the three areas analyzed in the study. The fingerprint ridge density in the ulnar and radial areas of the fingerprints is significantly higher than the lower area [8].

Esperanza Gutiérrez Redomero conducted this study to determine the topological and sexual differences in fingerprint ridge density (RD) in native subjects from two samples of northwestern Argentina (Jujuy province) living at different altitudes. The results were compared with those obtained from a Spanish population sample. The study was based on data from all 10 fingerprints of 393 adult Argentinian men and women, 193 from the Puna-Quebrada region (more than 2500 m above sea level) and 200 from Ramal (500 m above sea level). Ridge density was assessed for three different areas (radial, ulnar and proximal) for all 10 fingers of each subject. In both samples, significant differences between areas were obtained, so radial RD>ulnar RD>proximal RD. No significant differences were found between samples in males, while females from both samples significantly differed in the radial and proximal areas. Females have higher RD, so narrower ridges, than men, in all areas and all fingers [9].

Redomero in 2014 conducted this study to check whether there are differences between the RD of fingerprints depending on where the counting area is placed and how the fingerprints are obtained. Fingerprints of each finger were obtained from 102 adult Spanish subjects (50 females and 52 males), using two methods (plain and rolled). The ridge density of each fingerprint was assessed in five different areas of the dactylogram: two closer to the core area (one on the radial and the other on the ulnar side), two closer to the outermost area of each of the sides (radial and ulnar), and another one in the proximal region of the fingertip. Regardless of the method used and of the position of the counting area, thumbs and forefingers showed a higher RD than middle, ring, and little fingers in both sexes, and females present a higher RD than males in all areas and fingers. In both males and females, RD values on the core region were higher than those on the outer region, irrespective of the technique of fingerprinting used (rolled or plain). Regardless of the sex and location of the count area (core or outer), the rolled fingerprints exhibit RD greater than that of the plain ones in both radial and proximal areas, whereas the trend is inverted in the ulnar area, where rolled fingerprints demonstrate RD lesser than that of the plain ones [10].

Lalit Kumar conducted this study with an aim to establish a relationship between sex and fingerprint ridge density in Uttarakhand. The fingerprints were taken from 250 subjects (125 males and 125 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 < 12 ridges/25 mm^2 are more likely of male origin and finger print ridge of > 14 ridges/25 mm^2 are more likely of female origin. The study suggests that there are significant differences in epidermal ridge density between males and females and also support the hypothesis that women tend to have a statistically significant greater ridge density than men [11].

Neeti Kapoor in 2015 conducted this study to determine if any significant difference in the thumb- print ridge density of males and females in a central Indian (Marathi) population to enable the determination of gender. The study was conducted on 200 subjects (100 males and 100 females) in the age group of 18–30 years. Ridge densities on the right- and left-hand thumbprints were determined using a newly designed layout and analyzed statistically. The results showed that females tend to have a higher thumbprint ridge density in both the areas examined, individually and combined. Applying the t-test, the differences in the ridge densities of males and females at LoC (Left of Centre), RoC (Right of Centre) and Combined (LoC + RoC) were found to be statistically significant at $p < 0.01$ levels, proving the association between gender and fingerprint ridge density. Probability densities for men and women derived from the frequency distribution (at LoC, RoC and Combined) were used to calculate the likelihood ratio and posterior probabilities of gender designation for the given ridge count for subjects using Baye's theorem. [12]

Kewal Krishan conducted research with an aim to study the variability of palm print ridge density in a North Indian population, and its significance in inference of sex in forensic examinations. The sample consisted of 157 healthy young adults (110 females and 47 male) from Shimla city in North India. Bilateral palm prints were taken from all the participants following

standard methods. The palm prints were manually analyzed in four defined areas of each palm print that included the central prominent part of the thenar eminence (P1), the mount distal to the axial triradius on the hypothenar region (P2), the mount proximal to the triradius of the second digit (P3) and the mount proximal to the triradius of the fifth digit (P4). The ridge density was calculated diagonally using a square measuring 5 mm × 5 mm. The sex differences in palm print ridge densities were statistically analyzed for each of the designated areas using statistical considerations [13].

Nithin Mathew Sam carried out research with an aim to study the possibility of differentiation of gender using fingerprint ridge density. The study was conducted on 100 males and 100 females of South Indian Population, aged between 18 and 81 years, For calculating the finger print ridge density, the upper portion of the radial border of each print was chosen and the epidermal ridges in a defined area counted. Results showed that women have a significantly higher fingerprint ridge density than men. Application of Baye's theorem suggests that a fingerprint having ridge density of <14/25 mm^2 is more likely to be that of a male, and one having ridge density of >14/25 mm^2 is more likely to be that of a female [14].

Amit Chauhan conducted study on 60 samples including 30 male & 30 female aging from 18-55 years were taken from the population of Uttar Pradesh, North part of India. After the successful development of latent palm prints on documents, the ridge densities were taken from 25 mm^2 diameter. As a denouement, the procured mean ridge densities, if ≤ 11 ridges/25 mm^2 or less then is likely to be from male origin, and ≥13 ridges/25 mm^2 or more then that is likely to be from female origin [15].

Hale Oktem conducted research with an aim to study the fingerprint ridge density in Turkish population sample of Baskent University students. Fingerprints were obtained from 118 women, 88 men a total of 206 students aged between 17 and 28 years old by means of simple inking method. Fingerprints from all right and left hands fingers were collected in three different area of each. The ridges on fingerprints were counted diagonally on squares measuring 5 mm×5 mm on radial, ulnar and inferior areas. The fingerprint ridge density in radial, ulnar and inferior areas and between sexes was compared statistically Mann Whitney U test and Friedman test. The ridge density was significantly greater in women in every region studied and in all fingers when compared to men. The fingerprint ridge density in the ulnar and radial areas of the fingerprints was significantly greater than the lower area [16].

Noemi Rivalderia conducted research with an aim to analyze the fingerprint RD of two samples of the Argentinean population in order to assess their topological, digital, bilateral, sexual, and population differences for subsequent application in the inference of sex. Data were collected from the fingerprints of 172 individuals from the Buenos Aires province and 163 from the Chubut province. RD was assessed for three different count areas for all 10 fingers of each individual. In both sexes and both samples, significant differences among areas were obtained, so that radial-RD > ulnar-RD > proximal-RD. Females presented greater RD than males in all areas and on all fingers. Regarding population differences, no significant differences were found between the Buenos Aires and Chubut samples (except for proximal RD in males). However, both samples showed RD significantly different from that of the Jujuy province. The application of Bayes' theorem allowed for the identification of an RD threshold for discrimination of sexes in these Argentinean samples [17].

Pattanawit Soanboon conducted this study to determine the topological, age grouping and sexual differences in fingerprint ridge density (RD) in such populations. Fingerprints were collected from 353 unrelated volunteers (191 males and 162 females) and classified into three groups, that is, group A (total subjects), group B (14–18 years old) and group C (18–24 years old). RD was assessed for two topological areas, radial and ulnar. Significant differences between genders and age groups were obtained in both counting areas. Females exhibit higher RD i.e., narrower ridges, than males. A decrease in RD values with increasing age was also detected [18].

Siti Fairuz Abdullah conducted this study to test the truth of the relationship between the fingerprint ridge densities and the gender of a person born and lives in Malaysia as until now, no work on such study has been reported among the population. The sample of this study consists of 50 participants coming from the age group of 18- 60 year old and consists of 25 males and 25 females. The fingerprint images that taken manually will be going through the image pre-processing phase using a MATLAB software before the ridge of the fingerprint from two topological areas, radial and ulnar can be counted and the mean can be calculated. The results have shown that the fingerprint ridges of less than 12 ridges/25mm^2 is more likely belong to a male respondent while fingerprint ridges of more than 14 ridges/25mm^2 is more likely to be from a female respondent [19].

Amit Chauhan conducted research with an aim to acquaint about the fingerprints ridge density (25 mm^2) whether it vary for a specific age group at different places in likely to be equal environment. Study concluded that due to bodily growth of a specific group, counting of ridge density may vary in the adopted parameter or it can be differentiated by the profession (due to condition of fingerprints) of an individual. A minor change was noticed among the ridge density of the population of different parts of India, which may be an instrumental error/ factor of age/health and was not a significant identical feature of gender discrimination [20].

Materials and Methods

Creation of database

Fingerprint samples were collected from 190 (95 Male and 95 Female) people of various age groups ranging from 1-70 year from Marathwada population.

Methodology adopted

Fingerprint samples were obtained from the people of various age groups ranging from 1-70 year from Marathwada population for the purpose of this study, a fingerprint sample will refer to a single standard Federal Bureau of Investigation (FBI) ten-print card containing all ten inked fingerprint impressions of an individual. All samples were routinely collected using the standard protocol described by the FBI. This study focused on 190 randomly picked ten-print cards representing 190 individuals. Of these card samples, 95 were men and 95 were women. Epidermal ridges from fingerprint samples of both men and women were counted within a 5mm x 5mm square drawn on fingerprint impression slip at 5 different topological areas of fingerprint such as Upper Right, Upper Left, Middle, Lower Right and Lower Left. Diagonal ridges within each topological areas were counted and will be referred to as the ridge density value. For fingerprints from both the hands, this square were placed in following manner such as if it is an arch type of pattern then from the centre of fingerprint 0.25 mm lines were drawn at both right and left side and 5 mm square were drawn upside by considering middle line as a base line and from all for corners of square four 5 mm square were drawn at upper right, upper left, lower right and lower left

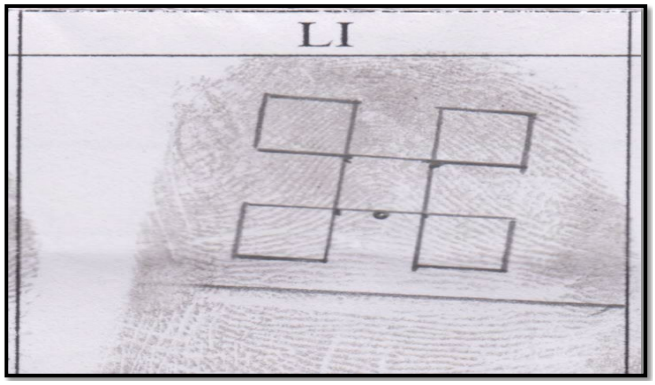

Figure 1. Illustration of the technique used to count dermal ridges in this study. All ridges within the depicted 5mm × 5mm square were summed. This value is referred to as ridge density and serves as the basis of comparison in this study.

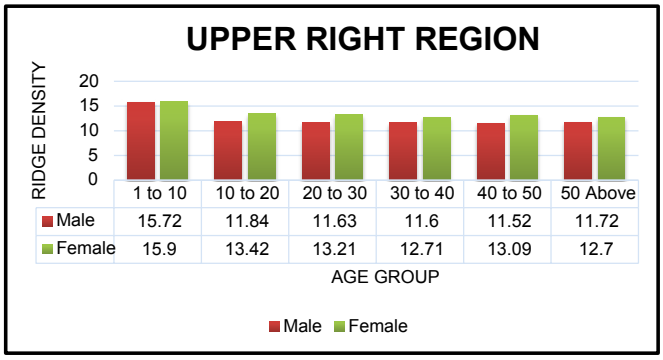

Figure 2. Shows ridge density of male and female taken over upper right region of the fingers. As shown in the figure the ridge density for age group 1-10 is similar for both male and female. However, there is a significant difference of ridge density for other age groups.

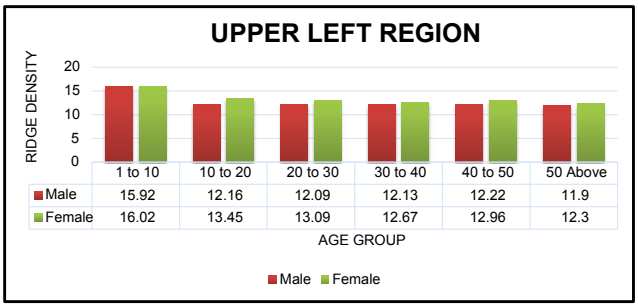

Figure 3. Shows ridge density of male and female taken over upper left region of the fingers. As shown in the figure the ridge density for age group 1-10 is similar for both male and female. However, there is a significant difference of ridge density for other age groups.

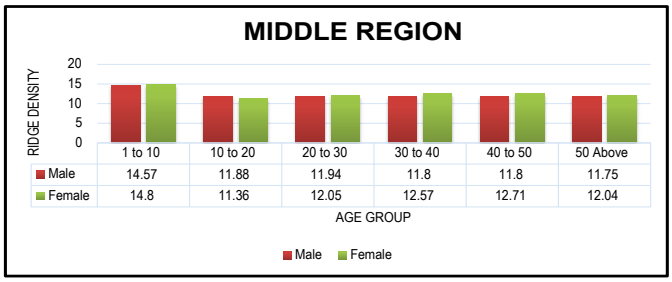

Figure 4. Shows ridge density of male and female taken over middle region of the fingers. As shown in the figure the ridge density for age group 1-10 is similar for both male and female. However, there is a significant difference of ridge density for other age groups.

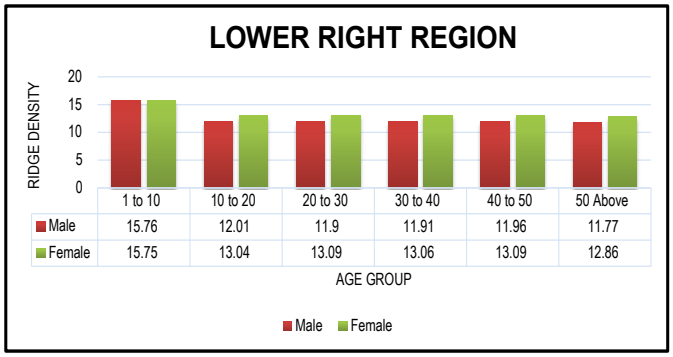

Figure 5. Shows ridge density of male and female taken over lower right regionof the fingers. As shown in the figure the ridge density for age group 1-10 is similar for both male and female. However, there is a significant difference of ridge density for other age groups.

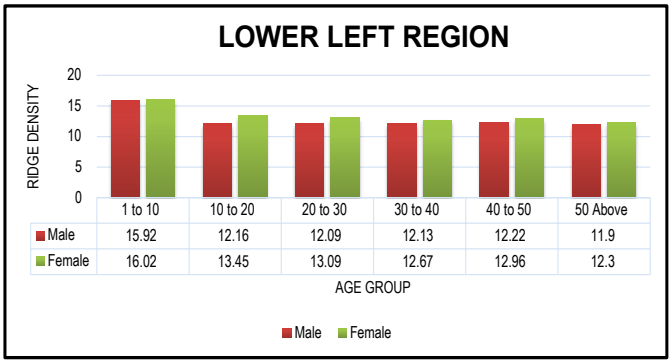

Figure 6. Shows ridge density of male and female taken over lower left region of the fingers. As shown in the figure the ridge density for age group 1-10 is similar for both male and female. However, there is a significant difference of ridge density for other age groups.

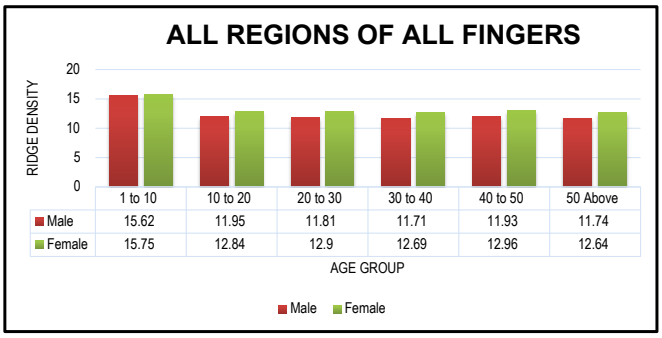

Figure 7. Shows ridge density of male and female taken over all the regions of the fingers. As shown in the figure the ridge density for age group 1-10 is similar for both male and female. However, there is a significant difference of ridge density for other age groups.

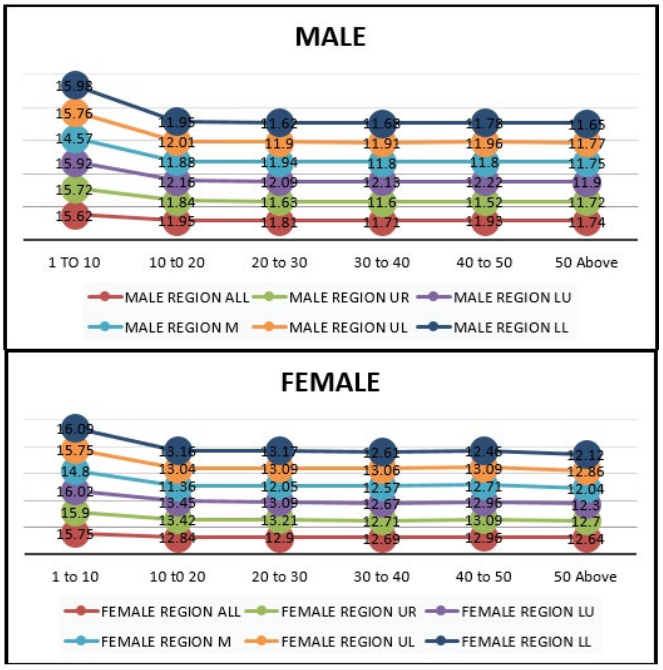

Figure 8. Shows that though there is highest number of ridge density for male and female for the age group 1-10 it has become consistent as the age progress from 10 years.

region. For both loop and whorl type of pattern core is considered as middle point and 5 mm square were drawn by following the same procedure. Figure 1 depicts the routine placement of the square on a fingerprint sample from the left hand. This sampling method serves to isolate ridges within a well-

defined area for this study, hence facilitating the process of ridge counting. This method also provides a technique that is highly reproducible for counting ridges in all samples.

Results

After ridges were counted for five different topological areas of all 10 fingers of each individual, the mean ridge density was calculated for each topological areas of each subject. This value represents a single data point for that individual (Figures 2-8).

Discussion

It can be observed from the figure that ridge density is the highest among the children who decreases with age and finally get stable. Statistical analysis (t-test) shows that there is no significant difference in ridge density after the age of 30 in case of both male and female. As far as sex determination is considered, there is no significant difference (statistically verified) in ridge density in the kids below 10 years of old while the female above 10 has significantly higher ridge density than that of male.

Conclusion

The present study was aimed to explore the potential of ridge density in sex identification. The variability due to well defined area for the calculation of ridge density was also explored. The study revealed that there is no significant difference in ridge density due to selected region. As far as variability due to age is concerned, it has been found that there is stability in ridge density once the age crosses 10 years. As far as identification of gender is concerned, there is a difference of 1-2 ridges when ridge density of male vs. female is calculated, which may be due to average over a small database.

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Declarations

I hereby declare that the research paper entitled "Exploring the potential of ridge density as a measure of sex identification" embodies the work carried out by me (Mr. Vilas Anil Chavan) under the supervision of Dr. Rajesh Kumar, Head of Department (Forensic Science), Government Institute of Forensic Science, Aurangabad. The work has been carried out at the Institute. It is further declared that this work is original and has not been submitted to any other journals.

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