Forensic Science International: Reports 10 (2024) 100378

Contents lists available at ScienceDirect

Forensic Science International: Reports

journal homepage: www.sciencedirect.com/journal/forensic-science-international-reports

General Forensics

Epidermal ridge sweat pore density: A forensic approach to sex determination

Jaisleen Kaur, Meenal Dhall *

Department of Anthropology, University of Delhi, Delhi 110007, India

ARTICLE INFO

Keywords:
Epidermal ridges
Personal identification
Poroscopy
Sex determination
Sweat pores

ABSTRACT

Determining the sex from an unidentified fingerprint recovered from a crime scene can assist in narrowing down the pool of potential suspects. The present study was conducted with the aim of determining sex using fingerprint epidermal ridge sweat pore density among the Indian population. For this purpose, plain prints from both the left and right thumbs were obtained from a total of 396 participants (191 males and 205 females), aged between 18 and 35 years, who were randomly selected for the study. Sweat pores were counted in a region of $3 \times 3\,mm^2$. Data were analyzed using SPSS (Statistical Product and Service Solutions) version 26 for Windows and Microsoft Office Excel 365. The likelihood ratio (LR) was calculated to obtain the probability inferences of sex based on the number of sweat pores. Analysis revealed that a fingerprint containing $\leq$ 45 pores/9 mm^2 is more likely to be of male origin while one containing $\geq$ 49 pores/9 mm^2 is more likely to be of female origin. Moreover, the difference in the number of pores was found to be statistically significant between the two biological sexes. The methodology employed in this study helps demarcate a uniform region in all the samples thereby eliminating variability due to pattern type and recurving ridges.

1. Introduction

Identification is the primary objective of any forensic examination. Fingerprints are unique, immutable, and classifiable and act as a reliable means of personal identification [1]. Fingerprints retrieved from the scene of crime (SOC) can be matched at three distinct levels [2]. The first level focuses on macrofeatures (pattern type, ridge count, core, delta, and orientation) which are insufficient for individualization [3]. The second level involves comparing the relative positions and nature of ridge characteristics, allowing for individualization. While, the third level utilizes microfeatures, including sweat pores, edge contours, friction ridge width, dots, incipient ridges, etc. [2],[4]. Level three details include a significant subset of extended features where pores are most prevalent [5].

In 1912, Dr. Edmond Locard from Lyons, France, pioneered the science of poroscopy [6]. It involves the study and analysis of sweat pore patterns on friction ridge skin to aid in personal identification [7]. Sweat pores are the openings of sweat glands and play a crucial role in thermoregulation [8]. Typically, there are approximately 2700 sweat pores per square inch of papillary skin [9]. Locard asserted that pores, similar to ridge characteristics, are permanent, immutable, and unique. He further proposed that a mathematical agreement between 20 and 40 pores is adequate for establishing identity [6]. Poroscopy is particularly useful when crime scene prints are blurred, partial, overlapping, oriented ambiguously, or contain a low number of minutiae [2,5,10].

Determining the sex from a recovered fingerprint can narrow down the list of potential suspects [11]. Numerous studies [12–20] have been conducted to investigate whether any relation exists between the fingerprint ridge density (FPRD), defined as the number of ridges per unit area, and sex of an individual wherein it has been observed that females tend to exhibit a significantly higher ridge density as compared to males. This can be attributed to the presence of finer epidermal ridges in females [12,14,21–23].

Likewise, attempts [24–26] have been made to determine whether there exists any relationship between the number of pores and sex of an individual. In a study conducted by Preethi et al. [25] it was observed that fingerprint containing $\leq$ 8 pores/25 mm^2 and $\geq$ 9 pores/25 mm^2 was more likely to be of male and female origin, respectively.

Abbreviations: **FPRD**, Fingerprint Ridge Density; **LCD**, Liquid Crystal Display; **LR**, Likelihood ratio; **NCR**, National Capital Region; **SOC**, Scene of crime; **SPSS**, Statistical Product and Service Solutions.

* Corresponding author.
E-mail addresses: neelsiaj@yahoo.com (J. Kaur), say2meenal@gmail.com (M. Dhall).

https://doi.org/10.1016/j.fsir.2024.100378
Received 1 May 2024; Received in revised form 26 June 2024; Accepted 30 June 2024
Available online 4 July 2024

Conversely, in studies conducted by Nagesh et al. [24] and Scobbie & Sofaer [26] statistically significant differences were not observed in pore counts between the two biological sexes.

Fingerprints recovered from crime scenes are frequently incomplete and lack adequate minutiae for matching purposes [6]. Furthermore, the absence of details necessary for determining sex complicates the identification process. The aforementioned reasons prompted the authors to undertake the present study. As females are known to exhibit finer and higher number of friction ridges as compared to males [12–20] it follows that they should also have a higher count of sweat pores. This forms the hypothesis for the present study which was undertaken with the aim to empirically assess the aforementioned hypothesis thereby exploring the potential of sweat pores in sex determination when examining a crime scene recovered fingerprint.

2. Material and methods

2.1. Sample collection

Plain prints from both the left and right thumbs were obtained from a total of 396 participants (comprising 191 males and 205 females) residing in the Delhi-National capital region (NCR). These participants, comprising college students and individuals involved in academia, aged between 18 and 35 years, were randomly selected for the study. The research protocol received ethical approval from the Ethical committee of the Department of Anthropology, University of Delhi, India (Ref. No./ Anth./2018/2880/28–12–18).

Prior to print collection informed written consent was obtained from all participants wherein, they were told about the objectives, relevance, and purpose of the study. The participants were also assured that the data collected would be used only for academic and research purposes. Individuals with any thumb injury (such as cuts, cracks, or scratches) were excluded from the study (hereditary or neurological disorders were not considered). All participants were asked to wash and dry their hands prior to the recording of prints. Both the left and right thumbprints were considered in the present study as the thumb is commonly used for grasping objects resulting in the likelihood of leaving prints on surfaces or objects it comes into contact with [27,28].

2.2. Procedure for collection

A thin and uniform layer of skin-safe black printer's ink was applied onto a glass slab using a fingerprint hand roller [27,28]. The ink was applied in such a manner that it allowed light to pass through it [24]. Each participant was instructed to gently press their thumb onto the ink-coated glass slab with moderate pressure (assessed qualitatively) following which a piece of clear tape was pressed onto the inked thumb of the participant (with minimal pressure) in order to capture the print [27,28]. This print-bearing tape was then affixed to a transparency sheet (measuring 2.75 × 1.75 in.) thereby creating a permanent record. All prints were anonymized, sequentially labelled, and stored. In total, 792 prints were collected and examined.

2.3. Pore counting

Sweat pores, regardless of type (closed, open on one side, or both sides), were counted from thumbprint samples of both males and females within a 3 × 3 mm square drawn on graph paper. This value represents the number of pores/9 mm^2. The pores were counted by overlaying the transparency sheet containing the fingerprint onto a graph paper and examining it using a digital microscope (Microware LCD Digital Microscope 7) equipped with a liquid crystal display (LCD) screen.

In work conducted by Preethi et al. [25] an area of 5 × 5 mm^2 was considered for counting the number of sweat pores however a region of 3 × 3 mm^2 was used in the present study since the authors wanted to ascertain whether or not sweat pores can help in determining the sex from an unknown print especially when it is fragmentary or partial thereby a minute region of 3 × 3 mm^2 which has not been used in any previous work was considered.

The methodology developed by Acree [12] was adopted to define the area for counting sweat pores (i.e., for fingerprints obtained from the right hand, the square was placed in the upper left quadrant of the central core region while, for prints obtained from the left hand, it was placed in the upper right quadrant of the central core region). This method is not only reproducible but also helps demarcate a uniform region in all the samples which is not affected by pattern type. In other words, a uniform region as described above, was considered so as to eliminate variability due to pattern type and recurving ridges.

2.4. Data analysis

Sweat pores were counted in both the thumbs of all participants. To counter any intra-observer variability, the principal investigator conducted three counts, and the mean was calculated for each participant (this mean value represents a single data point for that individual). This procedure was followed for all collected prints. Data were analyzed using SPSS (Statistical Product and Service Solutions) version 26 for Windows and Microsoft Office Excel 365. Before analysis, the data were checked to support the idea of normal distribution. Data points were compared using paired-samples t-test and independent samples t-test in SPSS. 95 % confidence interval and a significance level of $\alpha < 0.05$ were used to determine whether to reject the null hypothesis. Likelihood ratio (LR) was calculated in order to obtain the probability inferences of sex based on the number of sweat pores. To calculate the posterior probabilities Bayes' theorem was used. The following equation is the central factor in Bayes' theorem and was used to calculate the LR wherein, C and C' represent the male and female donor, respectively.

$$LR = \frac{\text{Probability of given fingerprint originating from male contributor (C)}}{\text{Probability of given fingerprint originating from female contributor } (C')}$$

For each pore density value, the likelihood ratio (C/C') was multiplied by the prior probabilities ($P(C)$ and $P(C')$) for both males and females. These products were then normalized by dividing each by the sum of the two products to obtain the posterior probabilities. Specifically, for a given pore density, the posterior probability for males was calculated as:

$$P(C|Pore) = (P(Pore|C) * P(C))/(P(Pore|C) * P(C) + P(Pore|C') * P(C'))$$

And for females as:

$$P(C'|Pore) = (P(Pore|C') * P(C'))/(P(Pore|C) * P(C) + P(Pore|C') * P(C'))$$

This process provided the likelihood of the fingerprint being from a male or female based on the observed number of pores, allowing to infer the sex of the individual from whom the fingerprint originated.

Table 1
Descriptive statistics of the number of pores per 9 mm² in male and female participants.

	Males	Females
n	191	205
Mean	45.15	52.47
Median	44.00	52.50
Mode	43.50	53.00[a]
Std. Deviation	6.04	7.00
Variance	36.49	48.94
Range	35	41
Minimum	30	37
Maximum	65	78

[a] Multiple modes exist. The smallest value is shown.

3. Results

Visual inspection of histograms, Q-Q plots, and Kolmogorov-Smirnov normality test showed that the data were normally distributed. Descriptive statistics of the number of sweat pores for male and female participants are shown in Table 1. Epidermal sweat pores ranged from 30-65/9 mm² for males and 37–78/9 mm² for females. Furthermore, the mean number of pores for males and females was observed to be 45.15 and 52.47 per 9 mm², respectively. Thus, females were found to possess a higher number of sweat pores than males. Frequency distribution of the observed number of pores in the two biological sexes is represented in Fig. 1. The graph shows the frequency distribution of the number of pores per 9 mm² for male and female participants wherein, the X-axis represents the number of pores (ranging from 30 to 78) and Y-axis represents the frequency i.e., how often each pore count occurs within the sample population. Epidermal sweat pores ranged from 30-65/9 mm² for males and 37–78/9 mm² for females. There is a notable distinction between the two distributions; males generally have lower pore counts, while females tend to have higher pore counts. Moreover, this graph visually supports the study’s finding that a lower number of pores per 9 mm² is more likely to be found in males, while a higher number of pores per 9 mm² is more likely to be found in females. This distinction can be useful for determining the sex of an individual based on fingerprint pore density. Independent samples t-test results, depicted in Table 2, show the number of pores to be statistically significant between the two biological sexes ($p<0.001$). Thus, establishing that males and females can be differentiated on the basis of number of epidermal sweat pores.

Since, both the right and left thumbs were evaluated in the present study, bilateral differences by sex were calculated and are represented in Table 3. It can be observed that the epidermal ridge sweat pore density did not show statistically significant differences between the left and right thumbs across both sexes. Thereby, suggesting that handedness does not affect the number of epidermal sweat pores. Furthermore, probability densities derived from frequency distributions were used to calculate the likelihood ratios based on Bayes’ theorem. Results show that a fingerprint containing 45 pores/9 mm² or less is more likely to be of male origin while that with 49 pores/9 mm² or more is more likely to be of female origin (Table 4).

4. Discussion

Females possess finer and higher number of friction ridges than males [12–20] thus, they should also possess a higher number of sweat pores. This hypothesis was empirically tested in the given research work. For this purpose 792 fingerprints were collected from 396 participants and analyzed. It was observed that a fingerprint containing 45 pores/9 mm² or less is more likely to be of male origin while that containing 49 pores/9 mm² or more is more likely to be of female origin. Moreover,

Table 2
Sex differences in epidermal ridge sweat pore density in relation to handedness.

	Males (n=191)		Females (n=205)		p-value
	Mean	Std. Deviation	Mean	Std. Deviation	
Left thumb	45.21	6.33	52.40	7.60	0.000
Right thumb	45.10	6.77	52.55	7.19	0.000

$p<0.001$

Table 3
Bilateral differences in epidermal ridge sweat pore density by sex.

	Mean	Std. Deviation	p-value
Males	-0.11	5.08	0.765
Females	0.15	4.82	0.664

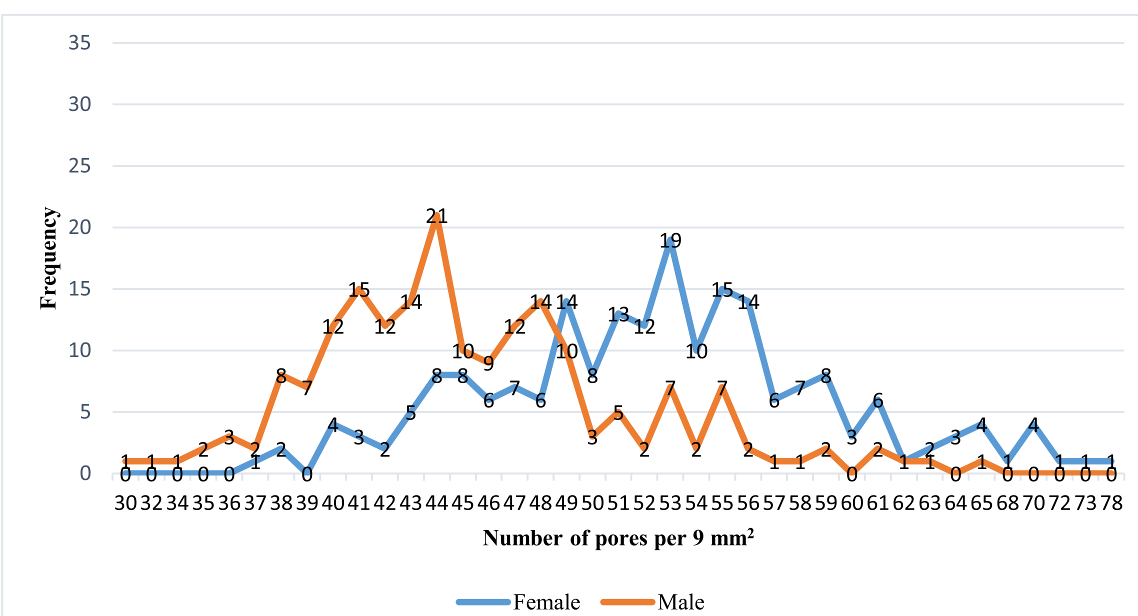

Fig. 1. Frequency distribution of epidermal ridge sweat pore density in male and female participants.

Table 4
Probability densities and likelihood ratios (LR) derived from observed number of pores for both males and females.

Number of pores/9 mm^2	Probability density		Likelihood ratio		Favoured odds	
	Males (C)	Females (C′)	(C/C′)	(C′/C)	P (C) = 0.5, P (C′) = 0.5	P (C) = 0.7, P (C′) = 0.3
≤ 36	0.02	-	-	-	-	-
37	0.01	0.00	2.15	0.5	-	-
38	0.04	0.01	4.3	0.2	Male (0.81) > Female (0.19)	Male (0.94) > Female (0.06)
40	0.06	0.02	3.2	0.3	Male (0.76) > Female (0.24)	Male (0.91) > Female (0.09)
41	0.08	0.01	5.4	0.2	Male (0.84) > Female (0.16)	Male (0.95) > Female (0.05)
42	0.06	0.01	6.4	0.2	Male (0.86) > Female (0.14)	Male (0.96) > Female (0.04)
43	0.07	0.02	3.0	0.3	Male (0.75) > Female (0.25)	Male (0.90) > Female (0.10)
44	0.11	0.04	2.8	0.4	Male (0.74) > Female (0.26)	Male (0.89) > Female (0.11)
45	0.05	0.04	1.3	0.7	Male (0.57) < Female (0.43)	Male (0.76) > Female (0.24)
46	0.05	0.03	1.6	0.6	Male (0.61) > Female (0.39)	Male (0.80) > Female (0.20)
47	0.06	0.03	1.8	0.5	Male (0.64) > Female (0.36)	Male (0.82) > Female (0.18)
48	0.07	0.03	2.5	0.4	Male (0.71) > Female (0.29)	Male (0.88) > Female (0.12)
49	0.05	0.07	0.8	1.3	Male (0.44) < Female (0.56)	Male (0.67) < Female (0.33)
50	0.02	0.04	0.4	2.5	Male (0.29) < Female (0.71)	Male (0.50) < Female (0.50)
51	0.03	0.06	0.4	2.4	Male (0.29) < Female (0.71)	Male (0.50) < Female (0.50)
52	0.01	0.06	0.2	5.6	Male (0.17) < Female (0.83)	Male (0.34) < Female (0.66)
53	0.04	0.09	0.4	2.5	Male (0.29) < Female (0.71)	Male (0.50) < Female (0.50)
54	0.01	0.05	0.2	4.7	Male (0.17) < Female (0.83)	Male (0.34) < Female (0.66)
55	0.04	0.07	0.5	2.0	Male (0.33) < Female (0.67)	Male (0.55) < Female (0.45)
56	0.01	0.07	0.2	6.5	Male (0.17) < Female (0.83)	Male (0.34) < Female (0.66)
57	0.01	0.03	0.2	5.6	Male (0.17) < Female (0.83)	Male (0.34) < Female (0.66)
58	0.01	0.03	0.2	6.5	Male (0.17) < Female (0.83)	Male (0.34) < Female (0.66)
59	0.01	0.04	0.3	3.7	Male (0.23) < Female (0.77)	Male (0.42) < Female (0.58)
61	0.01	0.03	0.4	2.8	Male (0.29) < Female (0.71)	Male (0.50) < Female (0.50)
63	0.01	0.01	0.5	1.9	Male (0.33) < Female (0.67)	Male (0.55) < Female (0.45)
65	0.01	0.02	0.3	3.7	Male (0.23) < Female (0.77)	Male (0.42) < Female (0.58)
≥ 68	-	0.02	-	-	-	-

it can be inferred from Table 4, that a sweat pore density of ≤ 36 pores/ 9 mm^2 is most likely (100 %) to be of male origin while that containing ≥ 68 pores/ 9 mm^2 is most likely (100 %) to be of female origin. Additionally, the results of the independent samples t-test, as shown in Table 2, indicate a statistically significant difference in the number of pores between the two biological sexes ($p < 0.001$) thereby, demonstrating that males and females can be distinguished based on the number of epidermal sweat pores. Furthermore, in this study, both the right and left thumbs were assessed and bilateral differences by sex were determined, as shown in Table 3. The results indicate that there are no statistically significant differences in epidermal ridge sweat pore density between the left and right thumbs for either sex. This suggests that handedness does not influence the number of epidermal sweat pores.

Similar findings were observed in work conducted by Preethi et al. [25], wherein statistically significant differences were observed between males and females in terms of the number of sweat pores (a fingerprint containing ≤ 8 pores/25 mm^2 was more likely to be of male origin whereas, that containing ≥ 9 pores/25 mm^2 was more likely to be of female origin). On the contrary, the number of pores was not found to be statistically significant between the two biological sexes in studies conducted by Nagesh et al. [24] and Scobbie & Sofaer [26].

Chovancova et al. [29] studied sexual dimorphism and bilateral differences in terms of fingerprint sweat pore shape within a 1 cm^2 region among the Slovak population. They observed that the order of sweat pore types in males was consistent on both hands, with the round type being the most common, followed by elliptical, triangular, rhomboid, square, rectangular, and hexagonal, the latter being the least frequent, similarly, in the female population, the order of sweat pore types was consistent on both hands, with the round type being most common, followed by elliptical, rhomboid, triangular, square, rectangular and hexagonal types [29]. Additionally, several statistically significant bilateral and inter-sexual differences were found in the studied sample population [29].

The similarity between the present research work and the study conducted by Chovancova et al. [29] lies in the utilization of a methodology to uniformly delineate a specific fingerprint area. In the present study, a region of 3 × 3 mm^2 was considered for counting the number of sweat pores since the authors wanted to ascertain whether or not sweat pores can help in determining the sex from an unknown print especially when it is fragmentary or partial thereby a minute region of 3 × 3 mm^2 which has not been used in any previous work was considered. To attain this aim, the methodology developed by Acree [12] was adopted to define the area for counting sweat pores (for fingerprints obtained from the right hand, the square was placed in the upper left quadrant of the central core region while, for prints obtained from the left hand, it was placed in the upper right quadrant of the central core region). This method is not only reproducible but also helps demarcate a uniform region in all the samples which is not affected by pattern type. Chovancova et al. [29], on the other hand, ensured effective and universally applicable delimitation of the evaluated area by developing their own methodology based on the dermatoglyphic pattern of each fingerprint; (i) a 1 × 1 cm template with a marked centre was prepared followed by identifying the centre of each dermatoglyphic pattern, (ii) the template was then placed such that its centre overlapped with the central point of the pattern to create a precisely defined area of the desired size, lastly (iii) these marked areas were evaluated using a USB digital microscope [29].

5. Conclusions

Fingerprints recovered from crime scenes are often incomplete and lack sufficient minutiae for effective matching. Moreover, the absence of necessary details for determining sex further complicates the identification process. The current study effectively demonstrated that females possess a higher number of sweat pores i.e., a fingerprint with 45 pores/ 9 mm^2 or fewer is more likely to be of male origin, while one with 49 pores/9 mm^2 or more is more likely to be of female origin. Additionally, it can be inferred that a sweat pore density of ≤ 36 pores/9 mm^2 is most likely (100 %) to be of male origin, whereas a density of ≥ 68 pores/ 9 mm^2 is most likely (100 %) to be of female origin. Furthermore, independent samples t-test results indicate a statistically significant difference in the number of pores between the two biological sexes ($p < 0.001$), demonstrating that males and females can be distinguished based on the number of epidermal sweat pores. However, no statistically significant bilateral differences in epidermal ridge sweat pore density between the left and right thumbs was observed for either sex, suggesting that handedness does not influence the number of epidermal sweat pores.

The methodology used in the present work is reproducible and helps demarcate a uniform region in all the samples so as to eliminate variability due to pattern type and recurving ridges. Thus, like FPRD, sweat pores can also help in determining the sex from an unknown fingerprint retrieved from the SOC especially when the retrieved print is fragmentary or partial in nature.

Future research can be carried out on a larger sample population, various ethnic groups can be considered, moreover, the sweat pore density of all ten digits can be explored using the methodology used in the present work.

Ethics approval and consent to participate

Ethical clearance (Ref. No./Anth./2018/2880/28–12–18) was obtained from the Ethical Committee of the Department of Anthropology, University of Delhi, India. Informed written consent was obtained from the participants prior to sample collection.

Funding

This work was supported by the University Grants Commission-Junior Research Fellowship (UGC-Ref. No.: 3556/(NET-JULY 2018)).

CRediT authorship contribution statement

Jaisleen Kaur: Writing – original draft, Validation, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **MEENAL DHALL:** Writing – review & editing, Supervision, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Acknowledgements

The authors would like to thank the University Grants Commission-Junior Research Fellowship (UGC-Ref. No.: 3556/(NET-JULY 2018)) for funding this research work. We are also thankful to all the participants.

Consent for publication

Not applicable

Competing interests

The authors confirm that this research article is an original work and has not been presented or published elsewhere nor is under consideration for publication elsewhere. The authors declare that they have no competing interests. Both authors have approved the manuscript for submission.

References

[1] H. Cummins, C. Midlo, Finger Prints, Palms and Soles: an Introduction to Dermatoglyphics, Dover Publications, New York, 1961.
[2] D.R. Ashbaugh, M.M. Houck, Fingerprints and admissibility: friction ridges and science, Can. J. Police Secur. Serv. 3 (2) (2005), 69-69.
[3] A.K. Jain, Y. Chen, M. Demirkus, Pores and ridges: high-resolution fingerprint matching using level 3 features, IEEE Trans. Pattern Anal. Mach. Intell. 29 (1) (2006) 15–27.
[4] A. Gupta, K. Buckley, R. Sutton, Latent fingermark pore area reproducibility, Forensic Sci. Int. 179 (2-3) (2008) 172–175.
[5] Q. Zhao, J. Feng, A.K. Jain, Latent fingerprint matching: utility of level 3 features, MSU Tech. Rep. 8 (2010) 1–30.
[6] D.R. Ashbaugh, Quantitative-Qualitative Friction Ridge Analysis: an Introduction to Basic and Advanced Ridgeology, CRC press, 1999.
[7] E. Locard, La poroscopie: nouvelles recherches, Arch. D. 'Anthropol. Crim., De. M. édecine légale Et. De. Psychol. Norm. Et. Pathol. 27 (1912) 308–340.
[8] F. Galton, Finger Prints, Macmillan, London, 1892, p. 246p.
[9] R.D. Olsen, Scott's Fingerprint Mechanics, Thomas, 1978.
[10] S. Oklevski, Poroscopy: qualitative and quantitative analysis of the 2nd and 3rd level detail and their relation, Fingerpr. Whorld 37 (145) (2011) 170–181.
[11] J. Kaur, M. Dhall, Useless or used less? Poroscopy: the evidence of sweat pores, Heliyon (2023).
[12] M.A. Acree, Is there a gender difference in fingerprint ridge density? Forensic Sci. Int. 102 (1) (1999) 35–44.
[13] E. Gutiérrez, V. Galera, J.M. Martínez, C. Alonso, Biological variability of the minutiae in the fingerprints of a sample of the Spanish population, Forensic Sci. Int. 172 (2-3) (2007) 98–105.
[14] E. Gutiérrez-Redomero, C. Alonso, E. Romero, V. Galera, Variability of fingerprint ridge density in a sample of Spanish Caucasians and its application to sex determination, Forensic Sci. Int. 180 (1) (2008) 17–22.
[15] E. Gutiérrez-Redomero, M. Alonso, J. Dipierri, Sex differences in fingerprint ridge density in the Mataco-Mataguayo population, Homo 62 (6) (2011) 487–499.
[16] E. Gutiérrez-Redomero, Á. Sánchez-Andrés, N. Rivaldería, C. Alonso-Rodríguez, J. E. Dipierri, L.M. Martín, A comparative study of topological and sex differences in fingerprint ridge density in Argentinian and Spanish population samples, J. Forensic Leg. Med. 20 (5) (2013) 419–429.
[17] K. Krishan, T. Kanchan, C. Ngangom, A study of sex differences in fingerprint ridge density in a North Indian young adult population, J. Forensic Leg. Med. 20 (4) (2013) 217–222.
[18] V.C. Nayak, P. Rastogi, T. Kanchan, K. Yoganarasimha, G.P. Kumar, R.G. Menezes, Sex differences from fingerprint ridge density in Chinese and Malaysian population, Forensic Sci. Int. 197 (1-3) (2010) 67–69.
[19] V.C. Nayak, P. Rastogi, T. Kanchan, S.W. Lobo, K. Yoganarasimha, S. Nayak, et al., Sex differences from fingerprint ridge density in the Indian population, J. Forensic Leg. Med. 17 (2) (2010) 84–86.
[20] M.D. Nithin, B. Manjunatha, D. Preethi, B. Balaraj, Gender differentiation by finger ridge count among South Indian population, J. Forensic Leg. Med. 18 (2) (2011) 79–81.
[21] G.A. Eshak, J.F. Zaher, E.I. Hasan, A.A.E.-A. Ewis, Sex identification from fingertip features in Egyptian population, J. Forensic Leg. Med. 20 (1) (2013) 46–50.
[22] E.A. Ohler, H. Cummins, Sexual differences in breadths of epidermal ridges on finger tips and palms, Am. J. Phys. Anthropol. 29 (3) (1942) 341–362.
[23] H. Oktem, A. Kurkcuoglu, I.C. Pelin, A.C. Yazici, G. Aktaş, F. Altunay, Sex differences in fingerprint ridge density in a Turkish young adult population: a sample of Baskent University, J. Forensic Leg. Med. 32 (2015) 34–38.
[24] K. Nagesh, S. Bathwal, B. Ashoka, A preliminary study of pores on epidermal ridges: are there any sex differences and age related changes? J. Forensic Leg. Med. 18 (7) (2011) 302–305.
[25] D.S. Preethi, M.D. Nithin, B. Manjunatha, B.M. Balaraj, Study of poroscopy among South Indian population, J. Forensic Sci. 57 (2) (2012) 449–452.
[26] R. Scobbie, J. Sofaer, Sweat pore count, hair density and tooth size: heritability and genetic correlation, Hum. Hered. 37 (6) (1987) 349–353.
[27] J. Kaur, M. Dhall, Reproducibility of fingerprint microfeatures, Egypt. J. Forensic Sci. 12 (1) (2022) 7.
[28] J. Kaur, M. Dhall, Reproducibility and reliability of fingerprint microfeatures: Effect of immersing hand in water at different temperatures, J. Forensic Leg. Med. 91 (2022) 102424.
[29] M. Chovancová, R. Beňuš, P. Švábová, S. Masnicová, Sexual dimorphism and bilateral difference of fingerprint sweat pore among Slovak population, J. Forensic Leg. Med. 94 (2023) 102487.