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A bimanual comparison of variation in sweat pores with sex and age: a brief dermatoglyphic survey of population in Delhi-NCR

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Abstract

Background Personal identification using partial fingerprints poses a major challenge in forensic investigations. In light of such restrictions, sweat pore characteristics have shown to be a possible alternative. However, limited research has been done on these due to their minute size. The present study was undertaken with the objective of studying the differences in pore frequency, pore shapes (circular and non-circular), and pore positions (middle and periphery) with respect to sex, bimanual, and age in the population of Delhi-NCR (National Capital Region). As there is no universal approach for defining the evaluation area of pore analysis, we used fingerprint patterns to demarcate a $9mm^2$ area of analysis. The rolled-inked fingerprints of 200 individuals (100 males and 100 females) belonging to 18-60 years of age were examined using microscopy.

Results The obtained data for all prints was analysed and compared with respect to the different variables. The results showed statistically significant bimanual variations for both sexes. In females, all studied pore characteristics except the number of pores at the middle position were significantly higher in the right hand as compared to the left hand. In males, only the number of pores at the peripheral position was significantly higher in the right hand as compared to the left hand. However, no significant differences were observed in pore characteristics between the two sexes and among the different age groups. Moreover, several pore characteristics showed a significant correlation with age in males as compared to females where no significant correlations were observed.

Conclusions Significant bimanual variations highlighted the potential application of pore characteristics for forensic practice; wherein a fingerprint examiner might determine the probable hand used for the commission of the crime, thereby strengthening the evidentiary value of partial fingerprints. These findings also suggest that the sex and age of an individual cannot be determined by pore characteristics.

Keywords Fingerprints, Pore characteristics, Poroscopy, Forensic science, Identification, Friction ridges

Background

Fingerprints are the impressions formed by friction ridges of fingertips that are unique and permanent (Baryah et al. 2023; Monson et al. 2019; Cummins and Midlo 1961). They are considered one of the most reliable types of evidence for identification in forensic communities (Baryah et al. 2023; Ali et al. 2021; Chen et al. 2021; Monson et al. 2019; Hazarika and Russell 2012). However, in certain cases, forensic experts struggle to recognize fingerprints due to numerous limitations like lack of an appropriate number of ridge characteristics, distorted and fragmented or partial prints (only a small portion of fingerprint), as a result, unfit for identification (Sun et al. 2023; Kaur and Dhall 2022; Nagesh et al. 2011; Gupta and Sutton 2010). To change these unfit

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prints into informative ones, researchers are now trying to gain additional information from fingerprints by utilizing smaller areas (Sun et al. 2023; Chen et al. 2022; van Dam et al. 2016). For the same, dermatoglyphic markers (pattern, ridge density, minutiae, etc.) have been analysed in relation to demographic features (Walton et al. 2019; Adamu and Taura 2017; Fournier and Ross 2016; Krishan et al. 2013). Subsequently, this helps in reducing the list of suspects and provides investigative lead in the case (Kaur and Dhall 2023; Adamu et al. 2018; Nayak et al. 2010). Sweat pore characteristics are one of those features (Chovancová et al. 2023; Chen et al. 2022; Preethi et al. 2012; Nagesh et al. 2011). These unique sweat pores vary in size, shape, type, number, interspace, and position and are very difficult to mimic. According to Locard, 20-40 sweat pores are sufficient to compare any two fingerprints which means if utilized properly they could be the best characteristic for recognition using partial prints (Chovancová et al. 2023; Kaur and Dhall 2022; Sharma et al. 2019; Preethi et al. 2012; Gupta and Sutton 2010; Bindra et al. 2000). However, limited research has been conducted on these features due to lack of uniform methodology, requirement of expensive instruments, time-commitment and tedious examination (Kaur and Dhall 2023; Chovancová et al. 2023; Chen et al. 2022; Bindra et al. 2000). In need of systematic data, an in-depth study of these characteristics among different populations using uniform methods becomes essential. The present study aims to analyse the sex, bimanual, and age difference in pore frequency, shapes, and positions. It includes the ten-digit fingerprints of an individual. No similar study involving the bimanual evaluation of digit prints in adults using poroscopy in the Delhi-NCR population is known so far.

Methods

Study participants

The ethical clearance for this study was approved by the Ethical Committee of the Department of Anthropology, University of Delhi, India. Prior to the data collection, written informed consent was obtained from the participants. Rolled fingerprint samples from 200 individuals (100 males and 100 females) were randomly collected from the adults aged between 18 to 60 years (Fig. 1). (Table 1) provides a summary of the demographic characteristics of the studied population. To examine the variations in pore characteristics with age, groups have been arbitrarily divided into four categories: Group A (below

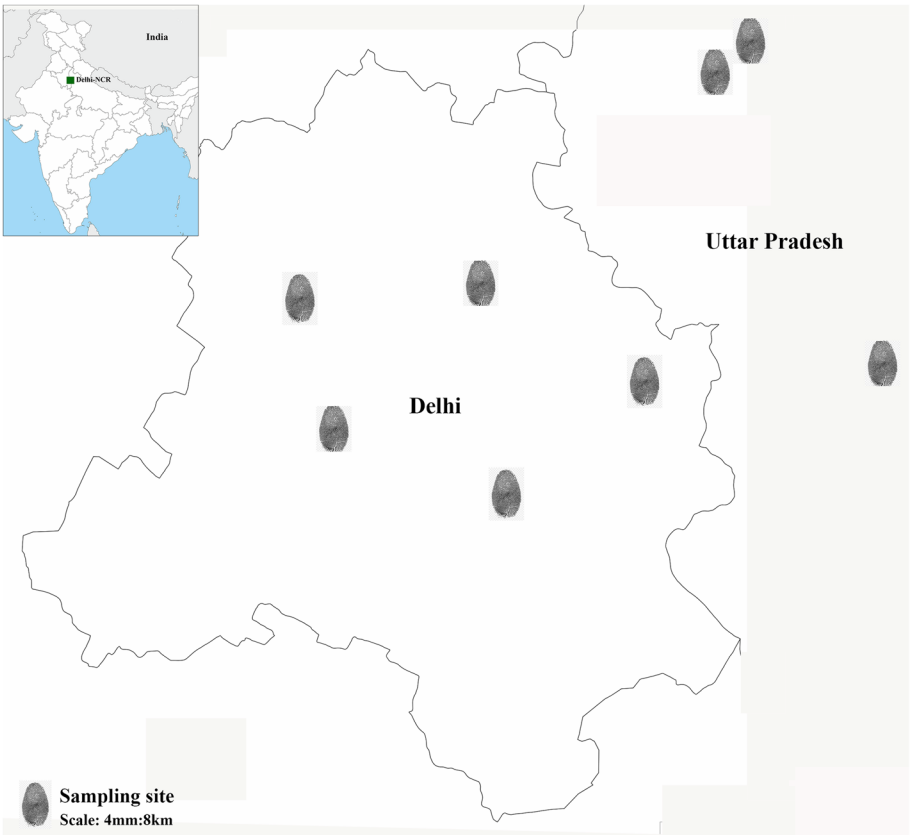

Fig. 1 Map showing sites of sample collection in Delhi-NCR region

Table 1 Summary of the demographic characteristics of the studied population

Sex	Number	Mean Age	Minimum	Maximum	Standard Deviation
Females	100	34.74	18	58	12.39
Males	100	31.99	18	59	12.93

30 years), Group B (30-39 years), Group C (40-49 years), and Group D (above 49 years). The number of individuals in each age group varied since the sample collection was random, with 110 individuals in group A, 20 in group B, and 37 in groups C and D. The study included samples that were clearly visible. We excluded samples from individuals who may have had changes in the sweat pores in their fingerprints due to amputations, burns, or skin diseases on or around the fingers.

Analyses of fingerprints

The ten-digit fingerprints of each individual were obtained using the ink method described by Cummins and Midlo (1961) on fingerprint sheets along with the name, sex, age, caste, and sample number. Once the samples were collected, they were examined using a magnifying glass and a polarizing microscope (Guandong Micro Accuracy Co. Ltd., Model No: LD-250). First, the core and delta were identified and marked in each print. Then, an 'Evaluated Area' i.e., a square of 3mm x 3mm, was drawn depending upon the type of fingerprint pattern (Fig. 2). Hence, all the squares were drawn in the distal portion of the print. A magnified view of these squares was analysed under the polarizing microscope to study pore frequency, pore shape, and pore position. Number of pores were counted and recorded in data tables created using Microsoft Excel 2010. Pore frequency was calculated by dividing the total number of pores by the area of the square ($9mm^2$). The pore shapes that were considered in the study were categorized into two groups i.e., Circular and Non-circular (all the other shapes like rhomboid, square, elliptical, etc.). The pore positions taken into consideration were Middle (pores within the ridge) and Periphery (pores at the edges or covering the whole of the ridge).

Statistical analyses

Statistical analyses for the present study were done using Statistical Product and Service Solutions (SPSS) software version 20. Shapiro-Wilk test was performed to test the normality of the data. Since the data were not normally distributed, measures of centrality were reported as median and interquartile range (IQR). Mann-Whitney U test was used to analyse sex and bimanual variations. The Kruskal-Wallis test was used for the comparative analysis of age groups. In addition, to understand the association of pore characteristics with age, correlation values were computed. P-values that were less than 0.05 were considered to be significant.

Results

Variation of pore characteristics with sex

The characteristics of pores under study showed variation between male and female subsamples in the population (Fig. 3). It was observed that median pore frequency was higher in males (212.83) than in females (205.22). The number of circular pores was comparable in the two sexes. Pores with non-circular shapes were found to be more prevalent in males (1709.00) as compared to females (1653.00). The number of pores at the middle and peripheral position was higher in males (681.00

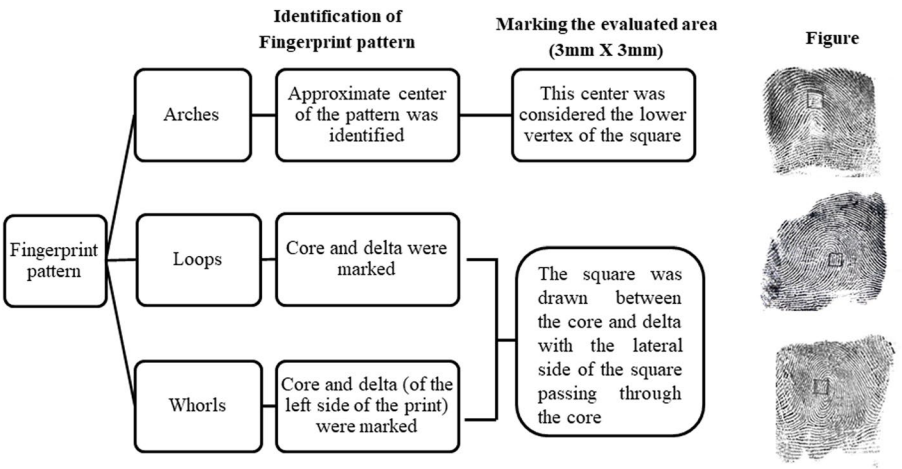

Fig. 2 Schematic representation of the methodology used to demarcate the evaluated area in this study

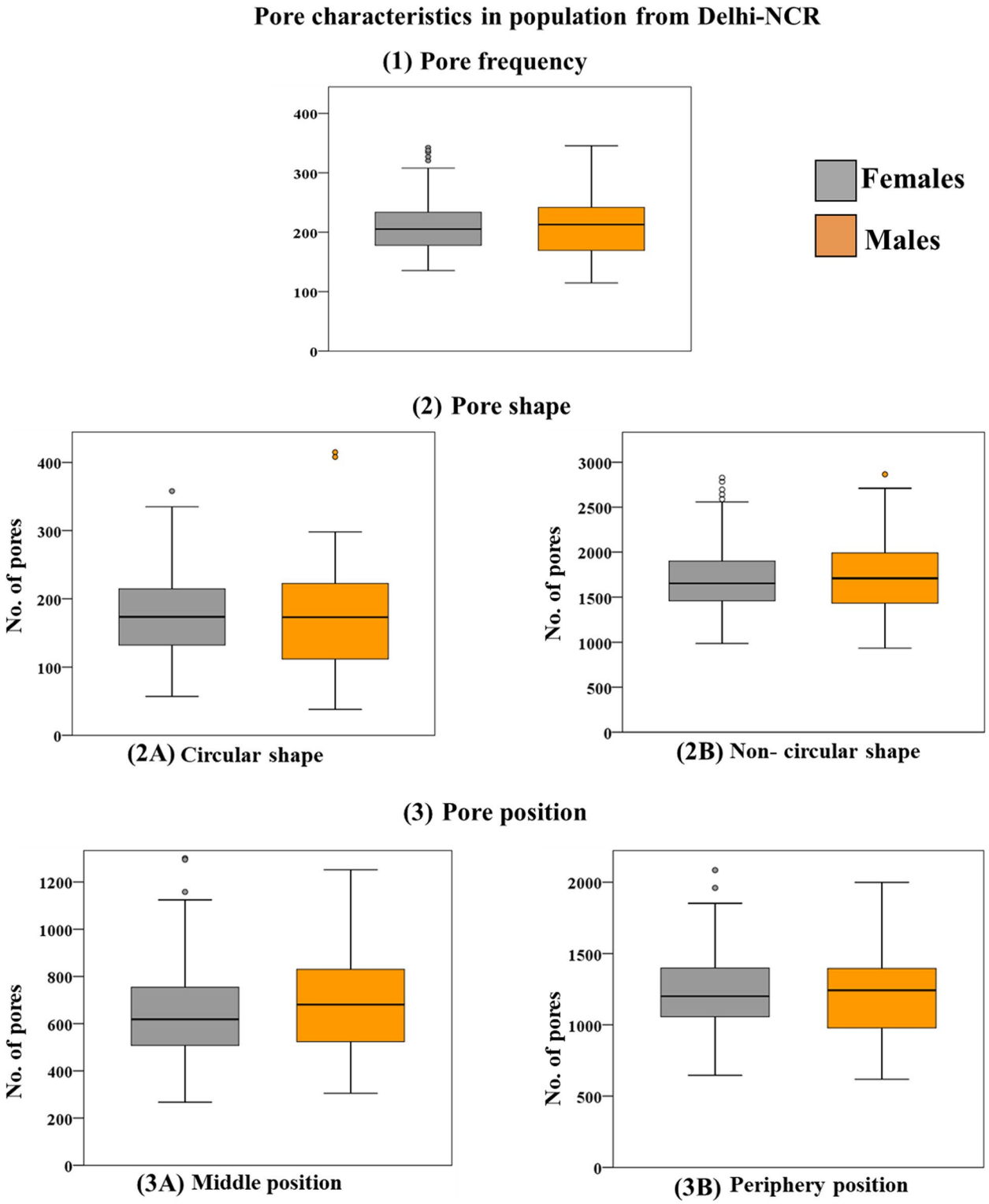

Fig. 3 Sex-wise Box-plot analysis for (1) Pore frequency, (2) Pore shape, (2A) Circular, (2B) Non-circular, and (3) Pore position, (3A) Middle, (3B) Periphery. Box represents interquartile range wherein the black line at the center of each box denotes median (50th percentile), the bottom line (25th percentile) and top line (75th percentile). The whiskers represent minimum and maximum. The dots above the box represent outliers of the data

and 1242.50) as compared to that in females (618.50 and 1200.50). However, these differences were not statistically significant (Supplementary Table 1).

Bimanual variations of pore characteristics in Females

Among female subjects, some pore characteristics showed significant trends of bilateral variation (Fig. 4). The median pore frequency was significantly higher in the right hand (112.50) as compared to the left hand (91.00). Similarly, the median count of circular (94.00) and non-circular (897.50) pores were significantly higher in the right hand in comparison to the left hand where it was 79.00 and 745.00 respectively. The number of peripheral pores was also significantly higher in the right hand (656.50) than in the left hand (539.50). Pores present in the middle of the ridge were more abundant in the right hand (333.00) than in the left hand (298.50); though this difference was not statistically significant.

Bimanual variations of pore characteristics in Males

Likewise, bimanual variations of the sweat pore characteristics were also observed in male individuals (Fig. 5). The median of pore frequency was higher in the right hand (109.50) than the left hand (102.00) though it was

Fig. 4 Box-plot analysis for (**a**) Pore frequency, (**b**) Pore shape, and (**c**) Pore position in right and left hand of female population. Box represents interquartile range wherein the black line at the center of each box denotes median (50th percentile), the bottom line (25th percentile) and top line (75th percentile). The whiskers represent minimum and maximum. The dots above the box represent outliers of the data. *$P<0.05$

Fig. 5 Box-plot analysis for (**a**) Pore frequency, (**b**) Pore shape, and (**c**) Pore position in right and left hand of male population. Box represents interquartile range wherein the black line at the center of each box denotes median (50th percentile), the bottom line (25th percentile) and top line (75th percentile). The whiskers represent minimum and maximum. The dots above the box represent outliers of the data. *$P<0.05$

not statistically significant. Likewise, pores of circular and non-circular shapes were abundant in right hand (87.00 and 882.50) than in left hand (78.50 and 840.50). The number of pores found at the periphery position was significantly higher in the right hand (622.50) than in the left hand (581.50). The number of pores at the middle position was also higher in the right hand (352.50) than in the left hand (332.50), however, this difference was not significant.

Bimanual variations of pore characteristics with Sex

The median values of pore frequency, pore shape (circular and non-circular), and number of pores at periphery position was higher, whereas the median value of pores at middle position was lower, in the right hand of females as compared to males, though these differences were not statistically significant (Supplementary Table 2). However, the median values of pore frequency, the number of non-circular pores, and the number of pores in the middle and periphery positions were lower, whereas the median value of the number of pores with circular shape was higher in the left hand of females as compared to males, though these differences were not statistically significant (Supplementary Table 2).

Pore characteristics and age

The pore characteristics showed variations among the different age groups (Table 2). The median pore frequency was highest in group C (220.33) followed by A (206.22), D (204.00), and B (185.88). A similar trend was observed for circular pores with group C with highest median (187.00) and group B with lowest median (133.50). The number of non-circular pores was also the highest in group C (1736.00) followed by D (1680.00), A (1652.50), and group B (1504.00). Pores present at middle position were also the highest in group C (690.00) and the least in group B (600.50). The number of peripheral pores was comparable in group D (1232.00) and C (1230.00) and different in group A (1190.00) and B (1035.50). Though differences were observed among age groups, they were not statistically significant for any considered variable (Table 2). To observe the relationship between pore characteristics and age for both the sexes as represented in (Table 3), correlation has been calculated. The results showed a significant positive relationship between pore frequency (r=0.234, p=0.019), and the number of non-circular pores (r=0.252, p=0.011), and the number of peripheral pores (r=0.250, p=0.012) in males. However, this positive correlation was not statistically significant for circular and pores at the middle position. Whereas, a negative relationship between pore characteristics and age was observed in females, however, it was not statistically significant (Table 3).

Discussion

The pore characteristics along with minutiae have the potential to be used as a reliable marker for personal identification, yet they are merely being applied in real case scenarios due to lack of uniform methodology and systematic data (Swathi et al. 2023; Chovancová et al. 2023; Kaur and Dhall 2022; Ali et al. 2021; Bindra et al.

Table 3 Correlation coefficients and p-values computed between pore frequency, shape, position and age with respect to sex

Pore characteristics X Age					
Sex	**Pore Characteristics**				
	Frequency	**Shape**		**Position**	
		Circular	**Non-circular**	**Middle**	**Periphery**
Males					
r	0.234	0.053	0.252	0.158	0.250
P-value	**0.019***	0.59	**0.011***	0.116	**0.012***
Females					
r	-0.064	-0.136	-0.050	-0.084	-0.038
P-value	0.526	0.177	0.623	0.408	0.709

r- correlation coefficient; * Significant at *p*-value <0.05

Table 2 Descriptive statistics and Kruskal– Wallis test values of pore frequency, pore shape and pore position in different age groups of the population

Age Groups (Years)	Pore Characteristics				
	Frequency	**Shape**		**Position**	
		Circular	**Non-circular**	**Middle**	**Periphery**
A (Below 30)	206.22 (232.86-172.41)	177.00 (214.00-128.00)	1652.50 (1921.00- 421.75)	647.00 (779.25-516.50)	1190.00 (1373.00- 1012.25)
B (31-39)	185.88 (231.83-155.08)	133.50 (185.75-86.00)	1504.00 (1886.50-1266.00)	600.50 (702.00-458.00)	1035.50 (1442.25- 867.25)
C (40-49)	220.33 (253.33-185.00)	187.00 (242.50-133.50)	1736.00 (2091.00-530.00)	690.00 (840.00-539.50)	1230.00 (1467.50-1097.00)
D (Above 49)	204.00 (241.72-182.83)	157.00 (214.50-116.00)	1680.00 (1990.00-1518.00)	591.00 (838.50-507.50)	1232.00(1431.50-1112.00)
***P*-value**	0.255	0.152	0.273	0.384	0.191

2000). In order to broaden their applicability and database worldwide, our study attempted to analyse sex, bimanual and age variation in pore characteristics. To the best of our knowledge, this is the first study that reported bimanual variations of pore characteristics from the Delhi-NCR population. In the present study, the 'Evaluated Area' of 9mm^2 was analysed from the distal portion of the fingertip, and the median of all ten digits was presented. In order to avoid any discrepancy that may occur due to inter and intra-individual variation in the type of fingerprint pattern, the central core region of the distal portion was selected as the position for the 'Evaluated area'. It has also been reported that the ridge density of this position shows the least ambiguity (Gutiérrez-Redomero et al. 2014). Though the study attempted to find a delineation method for the evaluation of the fingerprint area, there were certain shortcomings in the methodology of our study. Since the 'Evaluated Area' was kept constant, the ridge density of the area was different for every print. The variation arising due to the different number of ridges was not accounted for in this study. Our observations showed significantly higher median values of studied pore characteristics in the right hand as compared to the left hand in females except for the number of pores at middle position. However, no significant differences in pore characteristics were observed between the right and left hands of males except the number of pores at the peripheral position. Similarly, Chovancová et al. (2023) reported several bimanual differences in pore characteristics among males and females. These differences support the observations that hand laterality may affect ridge details (Kaur and Dhall 2023; Chovancová et al. 2023; Sánchez-Andrés et al. 2018; Ahmed and Osman 2016). This study reported no significant sex difference in pore frequency. Similarly, previous studies also found no significant sex difference in pore frequency (Bhagwat et al. 2020; Nagesh et al. 2011). On the contrary, a study conducted by Preethi et al. (2012) on the South Indian population found significantly higher pore frequency in females as compared to males. This variation is attributed to the fact that the number of friction ridges in a particular area i.e., ridge density, varies among different populations. Additionally, it has also been reported in literature that the density of ridges varied not only within different areas of the finger i.e., distal and proximal, but also between the fingers, resulting in the difference in the occurrence of pores (Chovancová et al. 2023; Sharma et al. 2021; Sánchez-Andrés et al. 2018; Ahmed and Osman 2016; Krishan et al. 2013). The findings of this study were concordant with Preethi et al. (2012) and Nagesh et al. (2011) which reported no significant differences in the number of pores of different shapes between the two sexes. However, Bhagwat et al. (2020) found a higher number of circular pores in males than females. This difference might result from variation in 'Evaluated area'. Bhagwat et al. (2020) evaluated the variation in pore shape in the 1cm ridge of only the left thumb, whereas our work presented the variance of ten digits in a specific region of 9mm^2. Our results showed higher number of non-circular pores than the circular ones in both the sexes which is similar to the study conducted by many researchers (Chovancová et al. 2023; Preethi et al. 2012; Nagesh et al. 2011; Bindra et al. 2000). However, Tafazoli et al. (2013) showed a greater number of circular pores in the people of Iran population. This contrast could have resulted from the difference in population and sex considered in the study. Our study reported no significant sex difference in number of pores at the two positions which was similar to the findings of Nagesh et al. (2011). Overall, in this study, number of pores lying at the peripheral position was higher in comparison to those in the middle position which was similar to the conclusion reported by Nagesh et al. (2011). Contrary to this, Tafazoli et al. (2013), found a higher number of pores at the middle position. However, Bindra et al. (2000) reported equal distribution of pores. This finding supports the observation reported by Nagesh et al. (2011) that pore position differs in various fingers and palms as both Tafazoli et al. (2013) and Bindra et al. (2000) examined palm and fingers wherein we studied only the tip of the fingers. The present study observed no significant difference in any of the studied pore characteristics among age groups. Nagesh et al. (2011) also found more pores at peripheral position and oval-shaped pores with increasing age in males, but the scope of our study is limited to the adult age group (18-60 years) only. Moreover, in this study, age was found to be positively correlated with pore characteristics in males. However, in females, a negative correlation was observed though it was not statistically significant. This correlation could be due to an increase in width of the ridge with age, as mentioned by previous studies, which could affect the pore size and shape (Burchill et al. 2023; Fowler et al. 2022; Sharma et al. 2021; Sánchez-Andrés et al. 2018; Nagesh et al. 2011).

Conclusions

The partial fingerprints found at the crime scene are very important for investigative leads. Therefore, uniform and standardized methods are required for the analyses of such prints. This study focuses on a specific 'Evaluated Area' rather than the entire fingerprints. The results of this study showed statistically significant bilateral variation in several pore characteristics. In females, pore frequency, number of circular and non-circular pores, and number of pores at the periphery position were significantly higher in the right hand as compared to the left hand. In

males, however, only the number of periphery pores was significantly higher in the right hand. The results suggest the possible application of pore characteristics in forensic investigations. It also showed no significant bisexual difference in pore characteristics as well as in different age groups. However, there was a significant positive correlation between pore characteristics and age only in males. To associate bimanual variations with demographic features, more work with similar methods and larger population and age groups of both sexes is recommended.

Abbreviations

mm	millimetre
mm^2	millimetre square
NCR	National Capital Region
SPSS	Statistical Product and Service Solutions
i.e.	That is
IQR	Interquartile range

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41935-023-00372-z.

Additional file 1: Table S1. Descriptive statistics and Mann-Whitney U test values of pore frequency, pore shape and pore position for both sexes in the population. **Table S2.** Descriptive statistics and Mann-Whitney U test values of pore frequency, pore shape and pore position in right and left hand for both sexes.

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Authors' contributions
SS: collection of data; performed the experiments, data analyses and writing the manuscript; PRM: conceptualized and designed the study; helped with the final reviewing and editing of the manuscript. Both the authors read and approved the final manuscript.

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Availability of data and materials
All data is available with the authors.

Declarations

Ethics approval and consent to participate
Ethical clearance for this study was approved by Ethical committee of Department of Anthropology, University of Delhi, India (Ref.No.Anth/2022-23/641). Prior to the data collection, an informed written consent was obtained from the participants.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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