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A Comparative Analysis of Predominant Fingerprint Patterns in Males and Females

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Abstract:

Dermatoglyphics, derived from the Latin term meaning "skin carving," is the scientific study of the epidermal ridge patterns on the palms, soles, and digits. Variations in fingerprint patterns between males and females, influenced by factors such as physical and chemical composition, heredity, and environmental conditions, have been extensively studied for forensic and biometric applications. The present study aimed to determine the most prevalent fingerprint patterns among males and females. A total of 80 individuals (40 males and 40 females) aged 18–30 years, all students of Uttaranchal University, Premnagar, Dehradun, were analyzed. The findings revealed that the loop pattern was the most dominant in both genders, with a frequency of 63% in females and 52% in males. This was followed by the whorl pattern, observed in 32% of females and 42% of males, and the arch pattern, which was the least frequent, appearing in 5% of females and 6% of males. Among subtypes, the ulnar loop was the most common in both genders, while the whorl pattern was more prevalent in females than males.

Keywords: *Forensic, Fingerprinting, Loop pattern, ulnar loop, Whorl.*

1. INTRODUCTION

The systematic study of fingerprints, termed dactyloscopy, gained prominence in the late 19th and early 20th centuries with the advent of classification systems that formalized their forensic application. (Hawthorne M, et.al. 2021) Fingerprint patterns are characterized by their unique ridge arrangements, which allow for reliable classification and comparison (Chopra M 2020). Even superficial injuries, such as cuts or abrasions, do not result in permanent changes to these patterns unless the damage penetrates the dermal layer (Karki, R. K., & Singh, P. K 2014). Based on the type of impression left, fingerprints are classified into latent, patent, and plastic prints. Latent prints are invisible impressions formed by the deposition of sweat and sebaceous secretions, requiring specialized techniques such as powder dusting or chemical reagents for visualization. Patent prints, on the other hand, are visible impressions produced when substances like blood, ink, or dirt are transferred from the finger to a surface. Plastic prints are three-dimensional impressions left on malleable surfaces such as wax, clay, or wet paint. Each type of fingerprint plays a crucial role in forensic science, aiding in linking individuals to crime scenes or objects through effective visualization and analysis techniques (Nagaraj G et. al 2015). Fingerprint ridge patterns are broadly categorized into loops, whorls, and arches, with further subdivisions within each group. Whorls, featuring circular or spiral ridge patterns, are sub-classified into plain whorls, central pocket loops, double loops, and accidental whorls. Arches, the simplest and least common pattern, are classified as plain or tented arches, with ridges flowing continuously from one side to the other without looping (Thakar MK et. al 2018). Gender and population based variations in fingerprint patterns have been extensively studied, revealing significant trends. Loops are more prevalent among females, with ulnar loops being particularly dominant, whereas males exhibit a higher frequency of whorls (Kücken M, Newell AC 2005). Arches, while relatively rare, occur slightly more often in females (Cummins H, Midlo C 1961).

Population-specific differences have also been observed; for instance, Indian males exhibit a higher prevalence of whorls, while Indian females predominantly display loops. Similar trends have been documented in African and European populations, highlighting the influence of genetic and environmental factors (Zaidi Z et. al. 2015). While traditional fingerprint analysis relies on ink-based or digital sampling techniques, modern advancements in machine learning and digital imaging have enhanced the accuracy and efficiency of pattern recognition (González M et. al 2020) .The focus of current research was to collect and analyse fingerprints for identifying gender-based differences in the fingerprints and statistically determine the significance of observed variations. Although considerable research has explored fingerprint pattern variability across populations, studies examining gender-specific differences remain limited. This gap presents opportunities for further investigation into the implications of these patterns in forensic and biometric fields. By advancing understanding of the interplay between genetic, environmental, and gender-based influences on fingerprint patterns, this research aims to contribute to the growing body of knowledge on human diversity and its applications in personal identification (Jain AK, Ross A 2015).

2. METHODOLOGY

This cross-sectional study was conducted on a sample of 80 participants with 10 sample from each participants with 800 samples size (40 males and 40 females) aged 18–30 years, recruited from Uttaranchal University, Dehradun, Uttarakhand. All participants were briefed about the study objectives in their native language, and informed consent was obtained prior to participation. Demographic details, including names, ages, and genders, were recorded on fingerprint forms to ensure accurate documentation. The equipment utilized for data collection included ink pads, magnifying glasses, fingerprint forms, and gauze cloth. Participants were instructed to thoroughly wash and dry their hands before the fingerprinting process to eliminate contaminants that might interfere with ridge pattern clarity. Fingerprints were obtained using the plain print method, where each participant pressed their fingertips laterally onto an ink pad to achieve even ink coverage and then imprinted all ten fingers on designated spaces on the fingerprint form. In addition, both thumbs were imprinted separately for detailed analysis. The collected fingerprints were classified into three primary pattern types—loops, whorls, and arches—and further subcategorized based on their morphological characteristics. A magnifying glass was employed to ensure accuracy in identifying and classifying these ridge patterns. Statistical analysis was conducted to evaluate the distribution of fingerprint patterns across genders. Frequencies and percentages were calculated to determine the prevalence of each pattern type among males and females. Statistical software was utilized to test the significance of the observed differences in pattern distribution, providing insights into gender-based variations. A total of 800 fingerprints were analyzed, comprising ten fingerprints from each of the 80 participants. The plain print method facilitated the identification of various patterns, including whorls, ulnar loops, radial loops, double loops, central pocket loops, tented arches, and plain arches

3. RESULTS AND DISCUSSION

The analysis of 800 fingerprints collected from 80 individuals (40 males and 40 females) revealed a distinct distribution of fingerprint patterns, including loops, whorls, and arches, along with their subtypes: ulnar loops, radial loops, double loops, central pocket loops, plain arches, and tented arches which has been shown in table 1.

Table1. *Fingerprint pattern in male and female fingerprint samples.*

Fingerprint Pattern	Males (n = 400)	Females (n = 400)	Total (n = 800)	Percentage (%)
Ulnar Loop	232	218	450	56.25%
Radial Loop	8	12	20	2.50%
Plain Whorl	84	120	204	25.50%
Double Loop	40	16	56	7.00%
Central Pocket Loop	16	16	32	4.00%
Plain Arch	16	8	24	3.00%
Tented Arch	4	12	16	2.00%
Accidental Whorl	0	0	0	0.00%

When analyzed by gender, ulnar loops emerged as the most dominant pattern among males (56.25%), followed by plain whorls (21%), double loops (10%), plain arches (4%), central

pocket loops (4%), radial loops (2%), tented arches (1%), and no occurrences of accidental loops, as shown in fig. 1. Among females (as shown in fig. 2), ulnar loops also dominated (54%), followed by plain whorls (30%), central pocket loops (4%), double loops (4%), radial loops (3%), tented arches (3%), and plain arches (2%), with no accidental loops recorded.

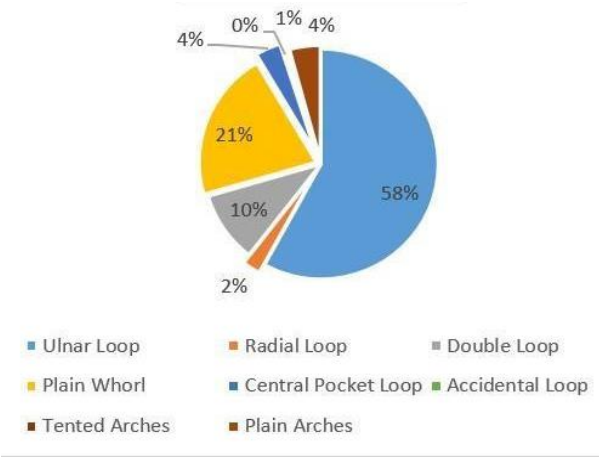

Figure1. *Fingerprint patterns in male*

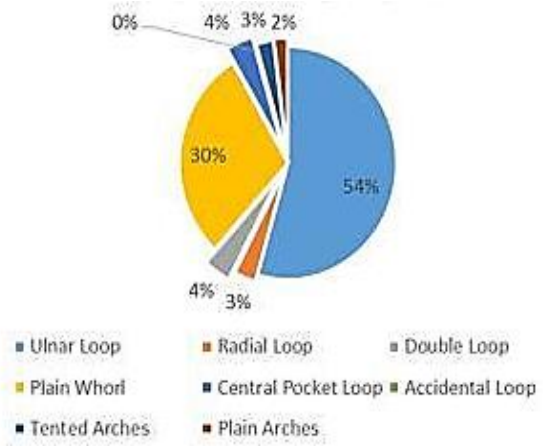

Figure2. *Fingerprint patterns in female*

The overall analysis revealed that loop patterns were the most frequent (473/800 or 59%), followed by whorl patterns (290/800 or 36%) and arch patterns (37/800 or 5%), as shown in fig. 3. Ulnar loops were identified as the most dominant fingerprint subtype across both genders, reinforcing the conclusion that loops are the most common fingerprint pattern.

The findings align partially with previous studies, which noted similar dominance of loops and varying frequencies of whorls and arches. While most studies reported a higher prevalence of loops globally (around 65%), this study aligns more closely with findings in specific regional populations, where loop frequencies ranged from 55% to 60%. Differences in the frequency of whorls and arches, particularly in specific fingers (e.g., ring fingers showing a higher prevalence of whorls), were noted across studies. This study discussed a detailed gender-based examination of fingerprint patterns like whorl, loop and arches in Dehradun, Indian population, specifically among students from Uttaranchal University. While previous research has examined fingerprint pattern variability across different populations, there is research gap as limited studies have focused on gender-based differences within a localized demographic. The key contributions of this research include: The study confirms and extends previous findings on the prevalence of loop, whorl, and arch patterns in males and females, offering more precise statistical insights into fingerprint distributions. By analyzing 800 fingerprints from 80 individuals, this research strengthens forensic databases and contributes to improving gender identification through fingerprint analysis.The results align with global trends but also highlight regional variations in fingerprint distribution, particularly regarding the dominance of whorls in males and loops in females.The study supports the forensic utility of fingerprints in personal identification and gender classification, which can be valuable in criminal investigations, biometric security, and anthropology

4. DISCUSSION

The analysis of fingerprint patterns in males and females in this study revealed distinct trends in dermatoglyphic distribution, corroborating findings from prior research while also highlighting some unique regional variations. The three primary fingerprint patterns—loops, whorls, and arches—exhibited differing frequencies among the 80 participants (40 males and 40 females), supporting the hypothesis that fingerprint morphology can be influenced by biological and genetic factors. Loops were found to be the most prevalent fingerprint pattern among both males and females, constituting 59% of the total fingerprint samples analyzed. Among the loop subtypes, ulnar loops were significantly more frequent than radial loops.

This pattern aligns with global dermatoglyphic trends, where loops have consistently been identified as the dominant fingerprint category. The presence of ulnar loops in 58% of male and 54% of female fingerprints further reinforces the reliability of loop patterns in forensic and biometric identification. The study found a notable gender-based variation in the frequency

of whorls. Males exhibited a higher frequency of whorls (36%) compared to females (30%). The study's findings are largely consistent with previous dermatoglyphic studies, which have documented loops as the most dominant pattern, followed by whorls and arches. However, the observed loop frequency of 59% is slightly lower than the global average of 65%, suggesting regional variations that may be influenced by environmental and genetic factors.

The prevalence of whorls in males and the slight overrepresentation of loops in females are also in line with international trends. The statistical analysis of fingerprint distribution confirmed significant differences in pattern frequencies between males and females, reinforcing the potential use of fingerprint analysis in gender identification. While fingerprints remain primarily a tool for individual identification, the observed gender-based variations highlight their supplementary role in forensic investigations, particularly in cases where gender estimation can aid in narrowing down suspect profiles. The forensic significance of these findings extends beyond gender differentiation. The high prevalence of loops and whorls suggests their critical role in biometric authentication and forensic analysis. Law enforcement agencies and forensic experts can leverage these dermatoglyphic patterns to enhance identification methodologies, particularly in cases where partial prints are retrieved from crime scenes.

5. Conclusion

This study aimed to analyze the distribution of fingerprint patterns among 80 students from Uttaranchal (40 males and 40 females), focusing on the prevalence of loops, whorls, and arches. The loop pattern emerged as the most common, followed by whorls, while arches were the least frequent among both genders. Ulnar loops were the predominant subtype of loops in both males and females. Gender-based analysis revealed that loops were more frequent in females, while whorls were more prevalent in males. The observed distribution patterns in this study—loops (59%), whorls (36%), and arches (5%)—align with global trends but deviate slightly in gender-specific observations.

For females, loops (58%), whorls (38%), and arches (4%) were recorded, whereas males exhibited 60% loops, 35% whorls, and 5% arches. Subtype analysis further demonstrated that ulnar loops were dominant, covering 54% of female and 58% of male fingerprints, while radial loops accounted for 3% and 2%, respectively. Among whorl subtypes, plain whorls were more frequent in females (30%) compared to males (21%), whereas double loops (10%) and central pocket loops (4%) were consistent across genders. Arch subtypes were the least common, with plain arches (2% in females, 4% in males) and tented arches (3% in females, 1% in males). These findings corroborate the utility of fingerprint analysis as a reliable method for individual identification due to the uniqueness and distribution patterns of fingerprints. Although regional variations exist, the observed trends are consistent with global data, emphasizing the importance of fingerprints in forensic and biometric applications.

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