

FORENSIC APPROACH: ANALYSIS OF GENDER BASED VARIATION IN PALM PRINTS WITHIN PAKISTANI POPULATION

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ABSTRACT

Background: In the modern era of forensic science, palm prints are commonly used for criminal investigations and commercial purposes. For instance, prints from the base of the palm (or palm heels) are often found at crime scenes when a criminal removes their gloves during the commission of a crime, leaving their palm prints exposed to the environment. This research poses challenges for anthropologists and forensic experts. The goal of the current study is to examine the effect of gender factors on palm print patterns. Discriminatory features of palm prints were analyzed for their potential legal or commercial applications. **Results:** All palm prints were analyzed based on the following parameters: ridge density, T.DOT value, types of creases, and anthropometry. Using Statistix 8.1 software, the p-values and chi-square values of all palm prints were calculated and presented graphically for both hands. In this study, our results revealed that ridge density is higher in females than in males. Significant differences were observed in stature and hand measurements (length, width, strength) between the two genders, with males exhibiting significantly higher values than females. **Conclusion:** Various parameters such as ridge density, anthropometry, crease patterns, and the total degree of transversality determine the physical identity of individuals based on gender. A conclusive method for identifying gender from latent palm prints has been established, which will assist forensic experts and investigators in apprehending suspects.

Keywords: Forensic science, Ridge density, Anthropometry, Palm prints, Criminal investigation.

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INTRODUCTION

Forensic science is a historical discipline, often described as “science applied to law,” and serves as a critical tool for conducting thorough investigations against criminals. Reliable evidence, such as palm prints or fingerprints left at crime scenes, is essential for individualizing perpetrators [1]. These methods have long been utilized in law enforcement and forensic settings. Notably, approximately 30% of prints recovered from crime scenes are palm prints [2]. The rich texture and unique features of palm prints make them a powerful means of personal identification and authentication [3]. During fetal development, interactions between the fetus and its surroundings (the uterus/placenta) exert continuous subtle pressure on the skin, forming friction ridges.

Variations in this pressure lead to the creation of distinct patterns, which ultimately develop into palm prints. Fingertips also possess friction ridges containing numerous sweat pores. When these ridges come into contact with a surface, sweat deposits leave colorless impressions [4]. Studies have shown that dermatoglyphic patterns in medically introverted children differ from those of healthy controls, as well as from children with schizophrenia or intellectual disabilities. The inheritance of dermatoglyphics is governed by polygenetic principles [5].

Palm prints are a perfect biometric identifier due to their stability, permanence, and uniqueness [6]. The rich textural information of the human palm print

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establishes it as one of the most powerful methods for personal identification and authentication [7]. Palm prints remain stable over time, and as sweat is a colorless fluid, the latent prints left behind are invisible to the naked eye. However, their visibility can be enhanced through specialized techniques [8]. Both fingerprints and palm prints are critical for gender identification in criminal investigations and disaster scenarios [9]. Anthropometric measurements are crucial during mass disasters and criminal investigations. A key component of forensic identification involves the recovery of a hand at the scene. Previous research has focused on diverse populations, including Egyptian, Saudi (Ibrahim 2016), and cricket players from Pakistani U-19 and Malaysian U-19 teams. Gender identification through fingerprint analysis, particularly ridge density, was first highlighted by Acree (1999) and Gutiérrez-Redomero et al. (2008), who traced this concept back to the 1940s. However, few studies have been conducted on the topic since then. Only recently have detailed investigations been undertaken on Indian [10] and Spanish populations [11]. Palm prints are unique to each individual and contain more data than fingerprints. These prints are divided into four prominent regions: P1, P2, P3, and P4 [10]. In Caucasian populations, Arcee (1999) found that mean ridge density varied between genders and across age groups. This study revealed that females exhibit significantly higher ridge density than males, suggesting that latent palm print analysis can effectively estimate an individual's age [8].

Palm prints are regarded as reliable for full-person recognition due to their unique and permanent nature, making them a valuable complement to fingerprint analysis. Latent palm prints at crime scenes are vital for identifying suspects and establishing criminal activity [12]. The primary types of palmar wrinkles include spiral longitudinal, proximal transverse, and distal transverse wrinkles. Dar and Schmidt employed a topographic methodology to quantitatively analyze these wrinkles, measuring the Degree of Transversality



Figure1: Inked patent palm print.

(DoT) for each major wrinkle and calculating the Total Degree of Transversality (T-DoT). T-DoT serves as a useful parameter for evaluating palmar wrinkle patterns in patients with congenital, hereditary disorders, and autoimmune conditions such as rheumatoid arthritis [13].

MATERIALS AND METHODS

The study was exploratory, combining quantitative and qualitative research methodologies. It was conducted in the Department of the Institute of Molecular Biology and Biotechnology at the University of Lahore, Pakistan. Approximately 150 inked patent palm print samples (both right and left hands) were collected from participants across Pakistan, representing various age groups (15–37 years). Samples were obtained with careful adherence to ethical protocols and informed consent from all participants.

Participants were asked to complete a form detailing biological information, including name, age, height, weight, gender, blood type, and ethnicity. Prior to data collection, participants washed and dried their hands thoroughly. A thin, uniform layer of ink was applied to the palm using a roller to prevent smudging. Palm impressions were then taken on white drawing sheets placed on a smooth surface. Care was taken to ensure complete, detailed prints without overlapping (Fig 1).

Hand measurements (width, length, finger length, and grip strength) and palm crease analysis (major/minor flexion lines) were recorded (Table 1). Key regions, including the hypothenar, thenar, and anterior digital areas, were examined. A standardized measuring scale (cm) was used for consistency. For Total Degree of Transversality (T.Dot) analysis, a coordinate grid was manually drawn on palm print samples. Points A, B, and C (Figure 2) were defined as follows:

- A:** Postaxial end of the proximal crease of the second finger.
- B:** Postaxial end of the proximal crease of the fifth finger.
- C:** Vertex of an isosceles triangle formed by points A and B.

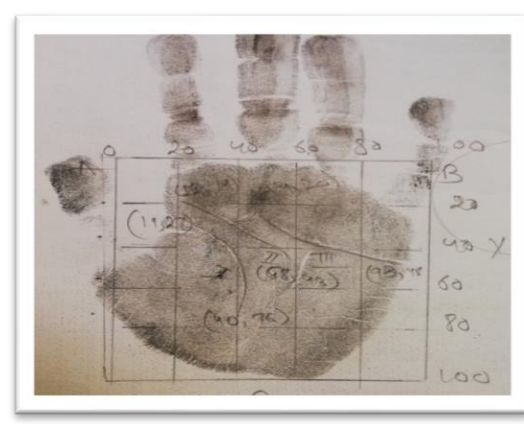


Figure 2: Grid of coordination points for T.Dot

Table 1: Incidence of closed, open and meeting.

Parameters	Male		Female	
	RH	LH	RH	LH
Close creases	20%	26.6%	22.6%	22%
Open creases	16%	10%	16.6%	20%
Meeting creases	14%	7.3%	11.3%	12%

Incidence of closed, open and meeting creases in Pakistanis according to sex and side shown the percentage of both sides in male and female. It shows that on the basis of gender and overall closes crease have high percentage in male left hand as compare to other and open creases have high percentage as compare to meeting creases.

The A–B line was divided horizontally into five equal segments (20 arbitrary units each), with 0 at the radial (A) and 100 at the ulnar (B) side of the palm (Figure 2).

Four distinct regions of inked palm prints were examined in the study. These included: The central prominent part of the thenar eminence (P1); The hypothenar region, inner to the proximal axial tri-radius (P2); The medial mount, proximal to the tri-radius of the second digit (P3); and The lateral mount, proximal to the tri-radius of the fifth digit (P4).

For ridge density calculations, rectangles were drawn over these regions and extended proximally along the palm, bordered by point C. Longitudinal coordinates were numbered sequentially, starting from 0 at line AB, thereby indicating the palm's length-to-width ratio. The study analyzed ridge density across these palm regions based on gender and race.

The four areas (P1, P2, P3, and P4) were examined on the palm prints (Figure 3). A standardized 5 mm × 5 mm square, drawn using a scale, was placed on the prints within these well-defined regions. This method ensured minimal error and maximum reproducibility of the study's methods and findings. The orientation of the 5 mm × 5 mm square for ridge counting was determined by the natural ridge patterns in each region. Accordingly, the square was placed in a standard orientation for P1 and P2, while it was rotated 90 degrees for P3 and P4 to align with their distinct ridge configurations.

RESULTS

Descriptive statistics for dermal ridge densities in the four designated areas of palm prints among male and female subjects, stratified by right and left hands, are presented in Table 2.

In Table 2 each race like (Mughal, Malik, Jutt, Khan, Rajpoot, and Arian) consist 10 participants. Four designated areas (p1, p2, p3, p4) on the palm prints that were analyzed for the palm print ridge density. Descriptive statistics: ridge density in races of both gender in the left hand Value of six races were selected overall identification chi square value, p

value and degree of freedom for left hand p is more than 0.05, so it's shown non significance result.

The mean palm print ridge density was observed to be greater in females than males across all four designated palm areas. Analysis of ridge density between genders revealed significantly higher values in females than males for all designated regions in both hands, except for the P3 area in the right hand.

Palm creases were quantitatively examined in both hands based on two primary crease types: radial longitudinal crease (I) and proximal transverse crease (II). Crease types were categorized as follows:

Closed crease (A): Creases I and II merge to form a common crease.

Open crease (B): Creases I and II remain separate.

Meeting crease (C): Creases I and II intersect but do not fully merge.

Closed creases were more prevalent in the left hands of males compared to females, while open creases were more common in females. Meeting creases (C) were also observed more frequently in females than males, as detailed in Table 3.



Fig. 3: Four designated area of palm print were analyzed for ridge density

In Table 3 normal 1 crease are found in male right hand is 10% and left hand 10 % as compare to female right hand is 10% and left hand is 13.3%. Normal 2 creases are found in male right hand is 10% and left hand is 7.33% as compare to female right hand is 7.33% and left hand is 6.6%. Stastical show that normal 1 creases are more frequent than normal 2 in participants of Pakistan population.

Statistical analysis of the t-test yielded a p-value of 0.01, indicating significance ($t\text{-value} = 0.011$; $\alpha = 0.05$). Consequently, the null hypothesis (H_0) was rejected in favor of the alternative hypothesis (H_1). Significant differences were also observed in stature and hand dimensions (length, width, and strength) between genders, with males exhibiting significantly higher values than females, as shown in **Table 4**.

Table 2: Chi-Square test for heterogeneity or independence.

1.	Observed	61	65	61	64	251
	Expected	62.34	62	62.67	63.99	
	Cell chi-sq	0.03	0.14	0.04	0.00	
2.	Observed	66	70	72	72	280
	Expected	69.54	69.17	69.91	71.39	
	Cell chi-sq	0.18	0.01	0.06	0.01	
3.	Observed	61	58	62	64	245
	Expected	60.85	60.52	61.17	62.46	
	Cell chi-sq	0.00	0.11	0.01	0.04	
4.	Observed	62	62	61	66	245
	Expected	60.85	60.52	61.17	63.99	
	Cell chi-sq	0.02	0.04	0.00	0.10	
5.	Observed	63	60	62	66	251
	Expected	62.34	62	62.67	63.99	
	Cell chi-sq	0.01	0.06	0.01	0.06	
6.	Observed	63	59	60	60	242
	Expected	60.10	59.78	60.42	61.70	
	Cell chi-sq	0.14	0.01	0.00	0.05	
		376	374	378	386	1514

Overall Chi-Square=3.24; P-Value=0.9993; Degrees of Freedom=15; Cases Included=24; Missing Cases=0

Table 3: Closed, open and meeting creases females and males.

Parameters	Male		Female	
	Right	Left	Right	Left
Normal 1	10%	10%	10%	13.33%
Normal 2	8%	7.33%	7.33%	6.66%

Table 4: Chi-square test for heterogeneity or independence.

1.	Observed	59	64	65	59	247
	Expected	62.87	60.22	62.87	61.04	
	Cell chi-sq	0.24	0.24	0.07	0.07	
2.	Observed	68	63	70	65	266
	Expected	67.71	64.85	67.71	65.74	
	Cell chi-sq	0.00	0.05	0.08	0.01	
3.	Observed	61	58	71	66	256
	Expected	65.16	62.41	65.16	63.27	
	Cell chi-sq	0.27	0.31	0.52	0.12	
4.	Observed	63	61	58	59	241
	Expected	61.34	58.75	61.34	59.56	
	Cell chi-sq	0.04	0.09	0.18	0.01	
5.	Observed	64	61	61	62	248
	Expected	63.12	60.46	63.12	61.29	
	Cell chi-sq	0.01	0.00	0.07	0.01	
6.	Observed	64	56	54	57	231
	Expected	58.80	56.31	58.80	57.09	
	Cell chi-sq	0.46	0.00	0.39	0.00	
		379	363	379	368	1489

Overall Chi-Square =1.13; P-Value=1.0000; Degrees of Freedom =15; Cases Included=24; Missing Cases= 0

DISCUSSION

Anthropological characteristics and the identification of chromosomal aberrations were analyzed through palm creases. In this study, a more objective morphological analysis of palm creases was developed. Additionally, based on the analysis of 3,216 Koreans, palm creases were interpreted anthropologically. A tendency for palm creases to be evenly distributed on the palm was observed, as recognized through the relationship between major and minor creases and the incidence of major crease types. The new method of analyzing palm creases is expected to be widely used for anthropological research and chromosomal diagnosis [14]. The current study has examined palm prints both qualitatively and quantitatively. It is based on a healthy Pakistani population of 150 individuals of different genders. Major creases were found more frequently compared to minor creases. In this study, research experts analyzed the T-dot values of 50 samples. The mean T-dot values from both hands (right and left) of students and laborers were examined. No significant difference was found between the right and left hands within either group (students: $p = 0.09$; laborers: $p = 0.724$) [15]. However, a statistically significant difference ($p = 0.046$) was observed in the left hand when comparing T-dot values between the two groups (students vs. laborers) across genders. The Total Degree of Transversality (T-dot) of palmar creases was statistically interpreted using patent prints. The results indicated a T-dot value of 0.01, with a significance level (t) of 0.011 (less than 0.05), leading to the rejection of the null hypothesis (H_0) and acceptance of the alternative hypothesis (H_1). A separate analysis involved 99 male adults (aged 20–72 years) from Abha, Saudi Arabia. Grip strength was measured using a hand-held dynamometer in kilograms, following standardized positioning and protocols [16]. Significant differences were observed in stature, hand length, hand width, and grip strength between genders, with males exhibiting higher values than females.

In another study, 60 samples (30 males and 30 females, aged 18–55 years) were collected from Uttar Pradesh, India. After developing latent palm prints on documents, ridge densities were measured within a 25 mm² area. The results demonstrated that mean ridge densities ≤ 11 ridges/25 mm² were likely

of male origin, while densities ≥ 13 ridges/25 mm² were likely female. This study confirmed that females exhibit higher ridge densities than males, supporting the use of palm print ridge density for sex differentiation.

A third study analyzed 150 samples (73 females, 79 males, aged 15–40 years) from Punjab, Pakistan. Ridge density comparisons between genders revealed significantly higher values in females across most palm areas (except the P3 area on the right hand). Statistically significant differences were observed between palm regions in both hands for males and females, though no significant right-left differences were found in males. Chi-square tests showed no significant racial differences ($p > 0.05$).

CONCLUSIONS

Useful anthropometric parameters that determine the physical identity of an individual include variations in palm prints. Specific regions of the palm, such as the thenar, hypothenar, and digital areas, are analyzed to assess ridge density, which differs across genders and racial groups. These patterns, though not yet fully understood by experts, can provide critical insights into a suspect's age and sex.

Our study identified multiplication factors that facilitate stature estimation based on right hand length for both males and females in Pakistan. This advancement could prove invaluable for professionals in forensic science, anthropology, and related medical fields.

Notably, each gender exhibits significant differences in epidermal ridge counts when categorized by racial group. Such findings could serve as pivotal evidence in legal contexts, strengthening the link between biometric data and a suspect's gender. Once sex determination is achieved, investigators can narrow down their search, streamlining the process of apprehending suspects.

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