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Ascertaining Association of Dermatoglyphic Pattern with Digits Using Correspondence Analysis Among Male and Female Convicted Prisoners

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Abstract. The present study is an attempt to evaluate an association of dermatoglyphic pattern with digits among convicted male and female prisoners. A total sample of 175 convicted prisoners (100 male and 75 female) and 175 controls (100 male and 75 female) ranging in age from 19 to 50 years was taken in the study. The data concerning fingerprints as well as criminal background of the prisoners was taken from different jails of Haryana (India). As per Henry's system of fingerprint classification, ulnar loop was the most frequently occurring pattern followed by a whorl single spiral and a whorl double spiral in the left as well as right hand of both the convicted prisoners and control group of both the sexes. Dermatoglyphic patterns whorl concentric and accidental were completely absent among the female prisoner as well as control group. Correspondence analysis among convicted male prisoner group recorded a significant association of whorl double spiral with the digits L1 and R1 (thumb) in both the hands, while in control group the association of digits L1 and R1 (thumb) was found with loop ulnar. In the convicted female prisoner group, whorl double spiral exhibited an association with digit L1 and R1 (thumb), while the first digit (L1 and R1) was associated with lateral pocket loop in control counterparts. Further cross-sectional studies in this sphere are needed to establish these findings.

Keywords: Forensic sciences; Dermatoglyphics; Divergent behavior; Prisoner.

1. Introduction

The beginning of criminal anthropology dates to the sixteenth century with the famous theories of Grataroli[1], Della Porta[2], and Gall[3]. The theory expounded by Lombroso[4]

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shifted the domain of delinquency from the legal to biological sphere. Hence, the manifestation of criminal behavior has been an important question as well as an issue of considerable concern and debate among many criminologists as well as psychologist since decades. Findings of Raine[5] attributed to various biological factors such as hormones and neurotransmitters, genetics, neurological deficiency, psychophysiology, and non-genetic toxins as significant determinant in emanating aggressive tendencies. A study of Wright *et al.*[6] on behavioral genetics illustrated that a given phenotype of an individual is governed by heritability, shared environment and nonshared environment. Past literature[7,8] also enumerated that approximately 60% of variation in antisocial and criminal behavior is attributed to heritability, whereas 10% and 50% of variance is credited to shared environmental and nonshared environmental factors, respectively.

Previous researches demonstrated that dermatoglyphics has been widely used to diagnose various genetic diseases or congenital abnormalities[9,10,11] associations with antisocial behavior[12] and to characterize intra-population as well as inter-population variability[13,14] but very few studies have been carried out with reference to the criminal behavior of the individuals. Emre *et al*.[15] also studied association between finger ratio (2D:4D) and criminal behavior in bipolar disorder and demonstrated that a lower 2D:4D ratio may have more likelihood of developing bipolar disorder in males as well as predicting criminal traits prior to the crime being committed.

It was noticed by a previous study[16] that the formation of ridge configurations and nervous system occur concurrently during the intrauterine life which persuaded researchers to formulate hypothesis that certain type of personality trait could be linked to distinct dermatoglyphic pattern. The association between ridge density and explosive personality was studied by Kaur and Sharma[17] and they revealed that genetic component explained about 50% of the variation in ridge density. A recent study performed by Venurkar *et al.*[18] tried to decode human personality by using epidermal ridge patterns on the digits and palms. To strengthen methods to identify unknown offenders, Yarovenko[19] has also highlighted the necessity to design effective and reliable model for the same. Even though it is not feasible to conclusively prove that individuals exhibiting a particular fingerprint pattern are more likely to possess antisocial trait because an individual's propensity for criminal behaviour is influenced by environmental, social, and psychological conditions[20]. Hence, this study was

conducted with the objective to evaluate an association, if any, between dermatoglyphic pattern and digits using correspondence analysis among male and female convicted prisoners.

2. Methods

The current cross-sectional study consisted of a sample of 175 convicted prisoners (100 male and 75 female) and 175 controls (100 male and 75 female) with the age ranging from 19 to 50 years. Data was collected on criminal as well as control group from December, 2018 to May, 2021. The fingerprints of the prisoners were taken from various jails of Kaithal and Karnal (Haryana) after taking the permission from the competent authority. Authors were not allowed to click photographs in the jail premises. Detailed information regarding the kind of offences under which criminals were convicted also collected from the jail authorities. The male and female of the prisoner group (Fig. 1) were convicted for the following section under the Indian Penal Code (IPC) i.e. Murder and attempt to murder (302 IPC and 307 IPC), Rape (376 IPC), NDPS Act and Miscellaneous Offences (POCSO Act, 148-149 IPC, 323-326 IPC, 341 IPC, 379 IPC,392-397 IPC, 420 IPC, and 506 IPC). Ethical approval to perform the study was obtained from the Institutional Ethics committee, Panjab University, Chandigarh (PUIEC/2018/144/A-1/29/10 dated 06/12/18).

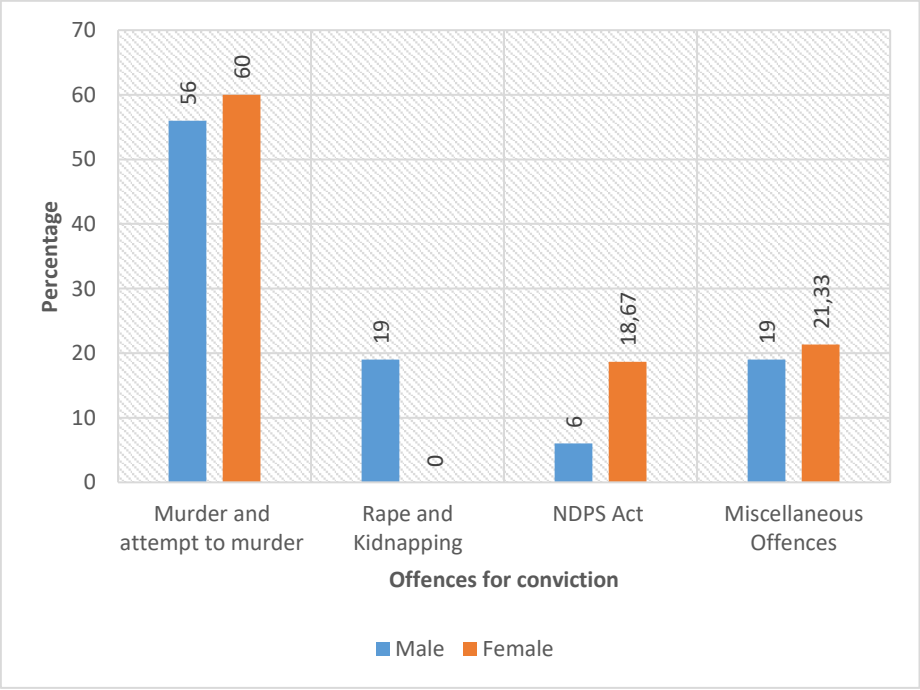

Figure 1. Classification of the prisoner group according to type of crime for conviction.

The individuals having no previous criminal record were randomly selected as the control group from district Panchkula (Haryana), which was verified from the concerned area police station. All the participants from control group were explained about the objective, as well as purpose of the study before taking their fingerprints. Their consent was obtained before taking their fingerprint. Participants of both the criminal and control groups, devoid of any type of skin problem, injury scars and deformity of the upper extremity were included in the study.

The rolled fingerprints of all the subjects were taken by following simple inking method as recommended by Cummins and Midlo[21]. Prior taking the fingerprints, hands of all the subjects were thoroughly cleaned with water and neutral detergent thereafter dried. A small quantity of printer's ink (Kores India) was taken on the inking plate. The printer's ink was uniformly applied on the finger balls with the help of inking pad. The subject was asked to keep his/her arm relaxed, so as to facilitate free movement of their fingers. To obtain neat and complete fingerprints, all the digits were evenly inked with the inking pad and properly rolled one by one. The fingerprints were taken starting from thumb, index finger, middle finger, ring finger and little finger for both the hands and the digits were numbered as L1, L2, L3, L4, L5 and R1, R2, R3, R4, R5 in left and right hand respectively.

Henry's system of fingerprint classification[22] was used to classify different patterns of the participants in the categories of Arches (plain and tented), Loops (radial and ulnar), Whorls (single spiral whorl, double spiral whorl, and concentric), Composites (lateral pocket loop, central pocket loop, twin loop, and accidentals). The main types of fingerprint patterns are displayed in Fig. 2.

3. Statistical analysis

Statistical Package for Social Sciences (SPSS) version 20 was used to evaluate percentage frequency of various dermatoglyphic patterns as defined by Henry's system of fingerprint classification[22] male and female prisoner and control groups. Chi square test was used to ascertain the level of significance, which was set at $p < 0.05$ and a confidence interval of 95% were considered for all statistical analyses. Correspondence analysis, a multivariate statistical tool, is a powerful graphical analysis of categorical data in a low-dimensional space. This analysis was employed to ascertain an association between different fingers and fingerprint patterns using Henry's system of fingerprint classification[22] of the subjects.

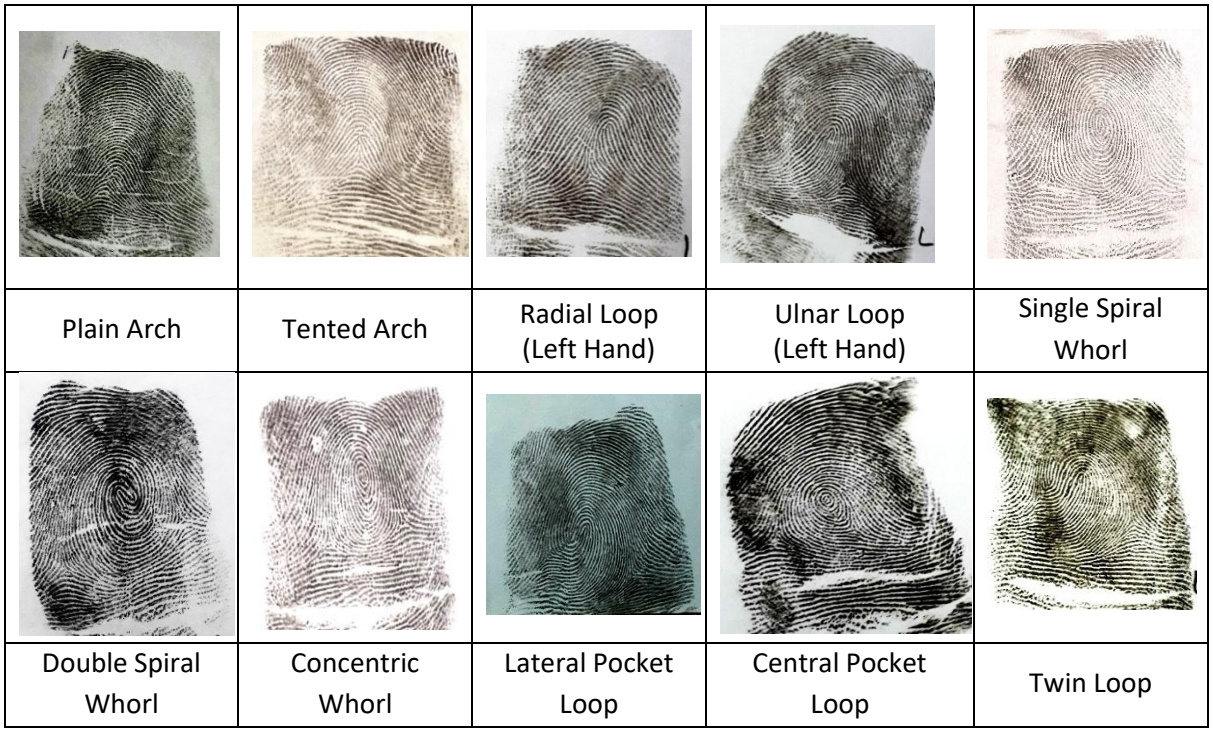

Figure 2. Main fingerprint patterns.

4. Results

Frequency distribution of different dermatoglyphic patterns on each digit of the left hand of convicted prisoner and control male group is presented in Table 1. It is evident from the Table that the ulnar loop was the most frequently occurring pattern followed by whorl single spiral and whorl double spiral in the left hand of study as well as control group. The digit wise frequency distribution of different dermatoglyphic patterns revealed that the ulnar loops were the most common patterns in the convicted prisoners as well as in controls, but the frequency of ulnar loops was significantly higher on all the digits of controls as compared to the study group (L1=59% vs 41%; L2=42% vs 37%; L3=66% vs 58%; L4=34% vs 32%; L5=77% vs 68%).

In the right hand of the male convicted prisoner group, a higher frequency of radial loops on all the digits were seen except digit II, where both the study as well as control groups exhibited equal frequency distribution i.e. 12% (Table 2). The overall frequency of whorl single spiral was slightly more in the prisoner group (25.2% vs 24.2%) than the control group, all the digit also noted same trend except for digit R4, where control group exhibited greater frequency of this pattern. Similarly, overall frequency of whorl double spiral (17.8% vs 13.4%) and whorl concentric (1.2% vs 1%) also presented higher frequency in prisoner group, with minor fluctuation on the trend

in the digits. Overall frequency of twin loop was higher in the controls except for the digit V (prisoner 0.2% vs control 1%). Both the right and left hands of the male convicted prisoners and control group demonstrated a complete absence of dermatoglyphic pattern accidental.

The frequency distribution of different dermatoglyphic patterns on the digits of left hand (Table 3) and right hand (Table 4) of female convicted prisoners and control group revealed that in left hand, overall frequency of plain (7.2% vs 5.33%) and tented arches (2.4% vs 1.33%) was more in the control group than the prisoner group (Table 3). The ulnar loops were more frequently occurring pattern in the prisoners than their control counterparts (58.67% vs 48.27%), whereas the frequency of the radial loops were higher in the controls except for digit V, where an opposite trend was observed for this pattern. The overall frequency of whorl single spiral (18.93% vs 17.6%) and whorl double spiral (10.13% vs 8.8%) was higher in the left hand of the female prisoner group with slight fluctuation of the pattern on the digits (Table 3).

The higher frequency of arches was observed on all the digits of the controls as compared to their prisoner counterparts on the right hand (Table 4). The frequency of ulnar loops was higher in prisoners except for the digit I (50.67% vs 52%) whereas occurrence of the radial loops was higher in controls, except for digit III (1.33% vs 0%). The overall frequency distribution also revealed that whorl double spiral was higher among prisoner group (11.73% vs 8.53%), while an inverse trend was seen in whorl single spiral (control 17.33% vs prisoner 15.73%). The overall frequency of lateral pocket loop (5.33% vs 2.67%) was more on the controls than the prisoner group.

The relationship between digits and different type of patterns was analyzed by Correspondence Analysis among convicted prisoners and control group. In the left (Fig. 3a) and right (Fig. 4a) hands of the prisoner male group the pattern whorl double spiral was significantly associated with digits L1 and digit R1 (thumb), while in control group the association of digits L1 and digit R1 (thumb) was found with loop ulnar. In the left hand of the prisoner group, the pattern central pocket loop appears to associate with index finger, but in controls it was associated with whorl concentric and plain arch.

Table 1. Frequency distribution of different dermatoglyphic patterns on each digit of the left hand of the males in convicted prisoner and control group.

Digit	Group	Digital Dermatoglyphic Pattern Types										
		Arches		Loops		Whorls			Composites			
		Plain N (%)	Tented N (%)	Radial N (%)	Ulnar N (%)	Single Spiral N (%)	Double Spiral N (%)	Concentric N (%)	Lateral Pocket Loop N (%)	Central Pocket Loop N (%)	Twin Loop N (%)	Accidentals N (%)
L1	Prisoner	2 (2%)	-	1(1%)	41(41%)	8 (8%)	26 (26%)	1 (1%)	12 (12%)	1 (1%)	8 (8%)	-
	Control	3 (3%)	-	-	59(59%)	7 (7%)	16 (16%)	-	5 (5%)	3 (3%)	7 (7%)	-
L2	Prisoner	2 (2%)	2 (2%)	6 (6%)	37(37%)	30 (30%)	13 (13%)	1 (1%)	9 (9%)	-	-	-
	Control	8 (8%)	1(1%)	11(11%)	42 (42%)	18 (18%)	15 (15%)	1 (1%)	2 (2%)	1 (1%)	1 (1%)	-
L3	Prisoner	3 (3%)	-	3 (3%)	58 (58%)	16 (16%)	16 (16%)	-	3 (3%)	1 (1%)	-	-
	Control	6 (6%)	-	-	66 (66%)	10 (10%)	15 (15%)	-	1 (1%)	1 (1%)	1 (1%)	-
L4	Prisoner	-	-	1 (1%)	32 (32%)	42 (42%)	17 (17%)	1 (1%)	3 (3%)	4 (4%)	-	-
	Control	-	1 (1%)	-	34 (34%)	39 (39%)	18 (18%)	-	3 (3%)	5 (5%)	-	-
L5	Prisoner	-	-	3 (3%)	68(68%)	13 (13%)	10 (10%)	-	4 (4%)	2 (2%)	-	-
	Control	-	-	-	77 (77%)	11 (11%)	7 (7%)	1 (1%)	2 (2%)	2 (2%)	-	-
Total	Prisoner	7 (1.4%)*	2 (0.4%)	14 (2.8%)	236 (47.2%)	109 (21.8%)	82(16.4%)	3 (0.6%)	**31 (6.2%)****	8 (1.6%)	8 (1.6%)	-
	Control	17 (3.4%)	2 (0.4%)	11 (2.2%)	278 (55.6%)	85 (17%)	71(14.2%)	2 (0.4%)	13 (2.6%)	12 (2.4%)	9 (1.8%)	-

L1, Thumb; L2, Index finger; L3, Middle finger; L4, Ring finger; L5, Little finger; Level of significance $p<0.05$ (*), $p<0.01$(**).

Table 2. Frequency distribution of different dermatoglyphic patterns on each digit of the right hand of the males in convicted prisoner and control group.

Digit	Group	Pattern Types										
		Arches		Loops		Whorls			Composites			
		Plain	Tented	Radial	Ulnar	Single Spiral	Double Spiral	Concentric	Lateral Pocket Loop	Central Pocket Loop	Twin Loop	Accidentals
R1	Prisoner	-	-	4 (4%)	35 (35%)	14 (14%)	37 (37%)	2 (2%)	6 (6%)	2 (2%)	-	-
	Control	1 (1%)	-	-	53 (53%)	10 (10%)	26 (26%)	1 (1%)	3 (3%)	3 (3%)	3 (3%)	-
R2	Prisoner	3 (3%)	2 (2%)	12 (12%)	24 (24%)	33 (33%)	13 (13%)	3 (3%)	6 (6%)	4 (4%)	-	-
	Control	3 (3%)	2 (2%)	12 (12%)	36 (36%)	26 (26%)	14 (14%)	1 (1%)	4 (4%)	1 (1%)	1 (1%)	-
R3	Prisoner	3 (3%)	-	6 (6%)	57 (57%)	17 (17%)	13 (13%)	-	1 (1%)	3 (3%)	-	-
	Control	2 (2%)	-	-	69 (69%)	10 (10%)	13 (13%)	1 (1%)	1 (1%)	3 (3%)	1 (1%)	-
R4	Prisoner	1 (1%)	-	3 (3%)	26 (26%)	46 (46%)	16 (16%)	1 (1%)	1 (1%)	6 (6%)	-	-
	Control	-	-	-	24 (24%)	60 (60%)	7 (7%)	1 (1%)	2 (2%)	6 (6%)	-	-
R5	Prisoner	-	-	5 (5%)	65 (65%)	16 (16%)	10 (10%)	-	-	3 (3%)	1 (1%)	-
	Control	-	-	-	66 (66%)	15 (15%)	7 (7%)	1 (1%)	3 (3%)	8 (8%)	-	-
Total	Prisoner	7 (1.4%)	2 (0.4%)	**30 (6%)****	207 (41.4%)	126 (25.2%)	89 (17.8%)	6 (1.2%)	14 (2.8%)	18 (3.6%)	1 (0.2%)	-
	Control	6 (1.2%)	2 (0.4%)	12 (2.4%)	248 (49.6%)	121 (24.2%)	67 (13.4%)	5 (1%)	13 (2.6%)	21 (4.2%)	5 (1%)	-

R1,Thumb; R2, Index finger; R3, Middle finger; R4, Ring finger; R5, Little finger; Level of significance $p<0.05$ (*), $p<0.01$(**

Table 3. Frequency distribution of different dermatoglyphic patterns on each digit of the left hand of the females in convicted prisoner and control group.

Digit	Group	Pattern Types										
		Arches		Loops		Whorls			Composites			
		Plain	Tented	Radial	Ulnar	Single Spiral	Double Spiral	Concentric	Lateral Pocket Loop	Central Pocket Loop	Twin Loop	Accidental
L1	Prisoner	1(1.33%)	-	-	40(53.33%)	5 (6.67%)	17(22.67%)	-	7 (9.33%)	-	5(6.67%)	-
	Control	4 (5.33%)	-	1 (1.33%)	34(45.33%)	10 (13.33%)	9 (12%)	-	12 (16%)	-	5(6.67%)	-
L2	Prisoner	7 (9.33%)	3 (4%)	3 (4%)	40 (53.33%)	13 (17.33%)	8 (10.67%)	-	1 (1.33%)	-	-	-
	Control	9 (12%)	3 (4%)	11(14.67 %)	25 (33.33%)	10 (13.33%)	9 (12%)	-	6 (8%)	2 (2.67%)	-	-
L3	Prisoner	6 (8%)	2(2.67%)	-	48 (64%)	14 (18.67%)	5 (6.67%)	-	0 (0%)			-
	Control	9 (12%)	6 (8%)	1 (1.33%)	35 (46.67%)	12 (16%)	6 (8%)	-	4 (5.33%)	1 (1.33%)	1(1.33%)	-
L4	Prisoner	4 (5.33%)	-	1 (1.33%)	34 (45.33%)	28 (37.33%)	6 (8%)	-	0 (0%)	2 (2.67%)	-	-
	Control	3 (4%)	-	1 (1.33%)	31 (41.33%)	22 (29.33%)	8 (10.67%)	-	7 (9.33%)	3 (4%)	-	-
L5	Prisoner	2(2.67%)	-	2 (2.67%)	58 (77.33%)	11 (14.67%)	2 (2.67%)	-	0 (0%)	-	-	-
	Control	2(2.67%)	-	1 (1.33%)	56 (74.67%)	12 (16%)	1 (1.33%)	-	2 (2.67%)	1 (1.33%)	-	-
Total	Prisoner	20 (5.33%)	5 (1.33%)	6 (1.6%)	220 (58.67%)	71 (18.93%)	38 (10.13%)	-	**8 (2.13 %)****	2 (0.53%)	5 (1.33%)	-
	Control	27 (7.2%)	9 (2.4%)	15 (4%)	181 (48.27%)	66 (17.6%)	33 (8.8%)	-	31 (8.27%)	7 (1.87%)	6 (1.6%)	-

L1, Thumb; L2, Index finger; L3, Middle finger; L4, Ring finger; L5, Little finger; Level of significance $p<0.05$ (*), $p<0.01$(**)

Table 4. Frequency distribution of different dermatoglyphic patterns on each digit of the right hand of the females in convicted prisoner and control group.

Digit	Group	Pattern Types										
		Arches		Loops		Whorls			Composites			
		Plain	Tented	Radial	Ulnar	Single Spiral	Double Spiral	Concentric	Lateral Pocket Loop	Central Pocket Loop	Twin Loop	Accidentals
R1	Prisoner	1 (1.33%)	-	-	38 (50.67%)	8 (10.67%)	14 (18.67%)	-	8 (10.67%)	1 (1.33%)	5 (6.67%)	-
	Control	3 (4%)	-	1 (1.33%)	39 (52%)	7 (9.33%)	12 (16%)	-	8 (10.67%)		5(6.67%)	-
R2	Prisoner	6 (8%)	1 (1.33%)	2 (2.67%)	39 (52%)	13 (17.33%)	8 (10.67%)	-	2 (2.67%)	4 (5.33%)	-	-
	Control	11 (14.67%)	3 (4%)	6 (8%)	29 (38.67%)	12 (16%)	7 (9.33%)	-	5 (6.67%)	2 (2.67%)	-	-
R3	Prisoner	2 (2.67%)	-	1 (1.33%)	59 (78.67%)	5 (6.67%)	8 (10.67%)	-		-	-	-
	Control	9 (12%)	3 (4%)	-	48 (64%)	7 (9.33%)	5 (6.67%)	-	3 (4%)	-	-	-
R4	Prisoner	1 (1.33%)	-	-	40 (53.33%)	25 (33.33%)	9 (12%)	-		-	-	-
	Control	3 (4%)	-	1 (1.33%)	29 (38.67%)	27 (36%)	7 (9.33%)	-	2 (2.67%)	6 (8%)	-	-
R5	Prisoner	1 (1.33%)	-	1 (1.33%)	59 (78.67%)	8 (10.67%)	5 (6.67%)	-		1 (1.33%)	-	-
	Control	2 (2.67%)	-	1 (1.33%)	56 (74.67%)	12 (16%)	1 (1.33%)	-	2 (2.67%)	1 (1.33%)	-	-
Total	Prisoner	**11 (2.93%)****	1 (0.27%)	4 (1.07%)	235 (62.67%)	59 (15.73%)	44 (11.73%)	-	10 (2.67%)	6 (1.6%)	5 (1.33%)	-
	Control	28 (7.47%)	6 (1.6%)	9 (2.4%)	201 (53.6%)	65 (17.33%)	32 (8.53%)	-	20 (5.33%)	9 (2.4%)	5 (1.33%)	-

R1,Thumb; R2, Index finger; R3, Middle finger; R4, Ring finger; R5, Little finger; Level of significance $p<0.05$ (*), $p<0.01$(**)

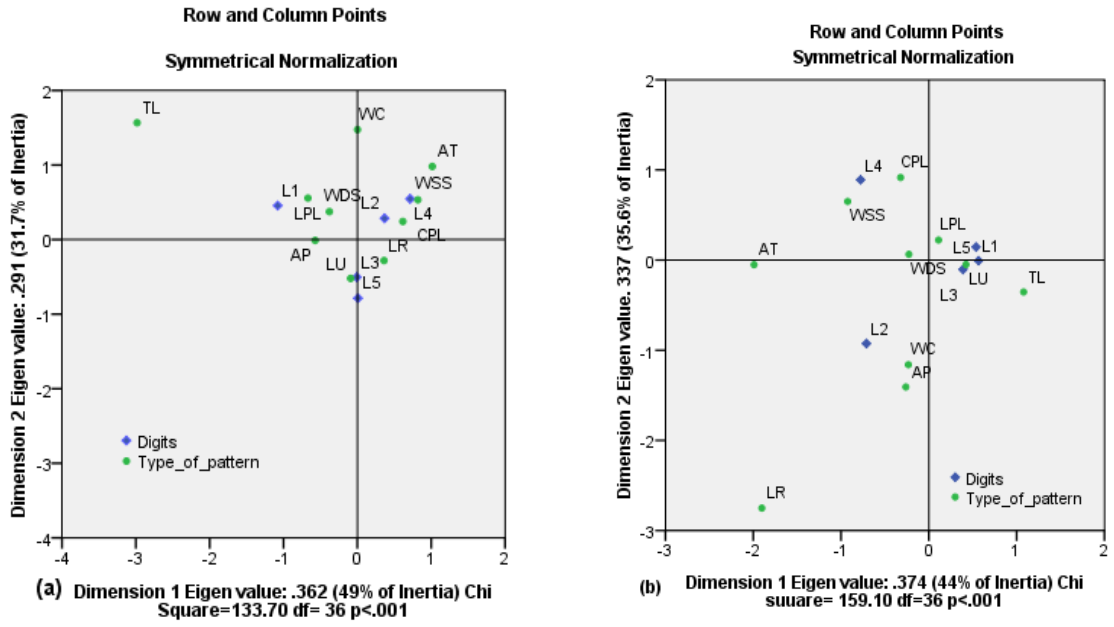

Figure 3. Correspondence analysis between digits of the left hand and different type of patterns (a) convicted male group (b) control male group. L1, Left thumb; L2, Left index finger; L3, Left middle finger; L4, Left ring finger; L5, Left little finger; AP, Arch plain; AT, Arch tented; LR, Loop radial; LU, Loop ulnar; WSS, Whorl single spiral; WDS, Whorl double spiral; WC, Whorl concentric; LPL, Lateral pocket loop; CPL, Central pocket loop; TL, Twin loop.

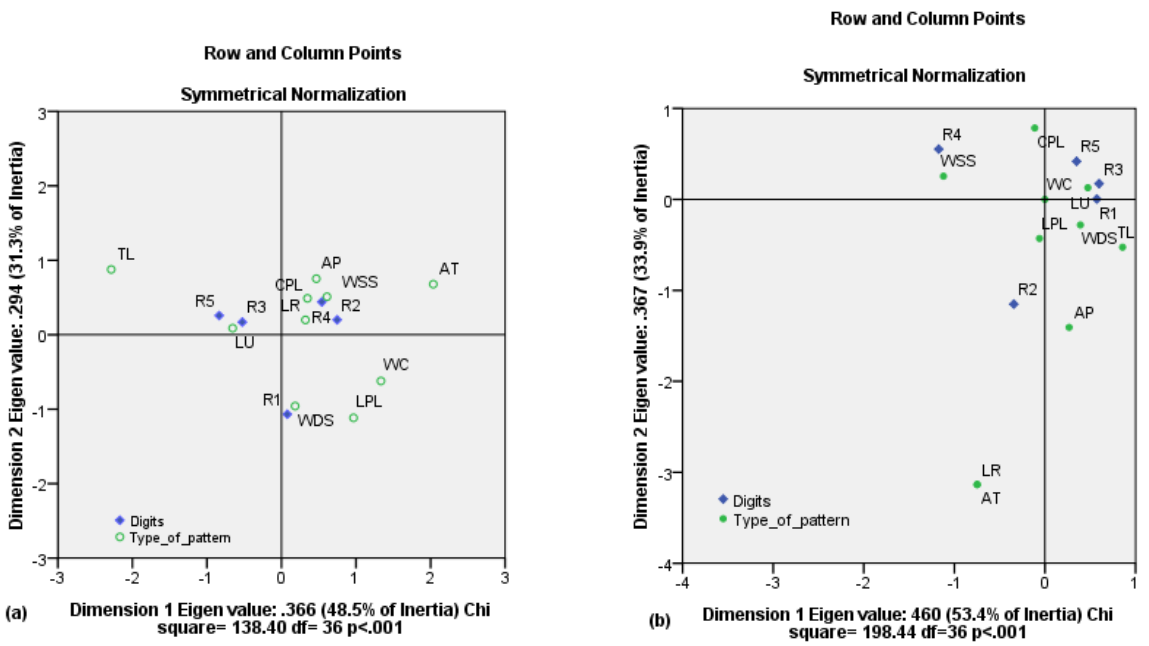

Figure 4. Correspondence analysis between digits of the right hand and different type of patterns (a) convicted male group (b) control male group. R1, Right thumb; R2, Right index finger; R3, Right middle finger; R4, Right ring finger; R5, Right little finger; AP, Arch plain; AT, Arch tented; LR, Loop radial; LU, Loop ulnar; WSS, Whorl single spiral; WDS, Whorl double spiral; WC, Whorl concentric; LPL, Lateral pocket loop; CPL, Central pocket loop; TL, Twin loop.

The Correspondence analysis between main patterns and fingers revealed that in both the left (Fig. 5) and right (Fig. 6) hands of female convicted prisoner group, the whorl double spiral appears to be associated with digit L1 and digit R1 (thumb) respectively, while first digit (L1 and R1) was associating with lateral pocket loop in control counterparts.

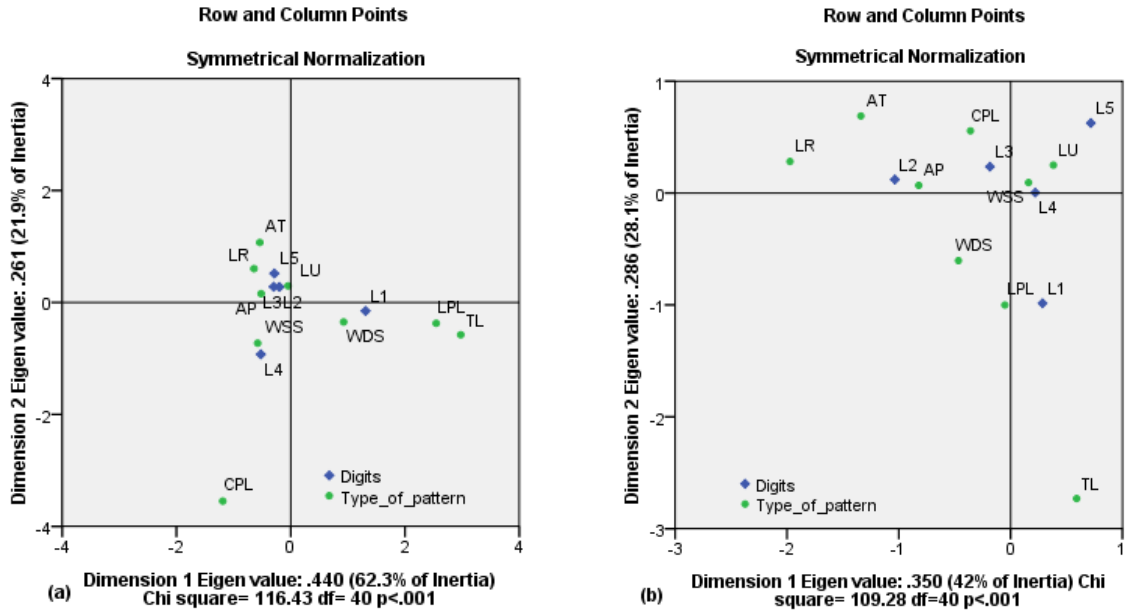

Figure 5. Correspondence analysis between digits of the left hand and different type of patterns (a) convicted female group (b) control female group. L1 Left thumb; L2 Left index finger; L3 Left middle finger; L4 Left ring finger; L5 Left little finger; AP Arch plain; AT Arch tented; LR Loop radial; LU Loop ulnar; WSS Whorl single spiral; WDS Whorl double spiral; LPL Lateral pocket loop; CPL Central pocket loop; TL Twin loop.

5. Discussion

For many decade fingerprints have been one of the most authentic markers of personal identification in both the civil and criminal cases due to their unique as well as permanent characteristics[23]. Owing to the alarming rise in the crime rate in recent times, fingerprints have emerged as an accurate and reliable tool for the investigating agencies as well as court of law. The present study observed that the frequency of the whorls was higher in male convicted prisoners as compared to controls, while the frequency of ulnar loops was higher among males in control group. Castilla[24] observed greater number of whorls in prisoners as compared to male and female control group. A comparative study was conducted by Pandey and Vyas[20] on Gujrati male convicts of Sabarmati jail and noticed that the frequency of whorls was higher among the convicts than controls, whereas an inverse trend was witnessed for the loops.

Similarly, to evaluate the possible role of fingerprints as predictive biomarkers of genetic criminal tendency, Sudha *et al.*[25] performed a case-control study and recorded that whorl patterns were more commonly occurring, and loop patterns were less frequently occurring in the hands of the criminals as compared to their control counterparts. Correlation between fingerprint patterns of convicted and non-convicted criminals was analyzed by Ranjan[26] and demonstrated that in convicted criminals, except for middle and little fingers rest of the fingers exhibited more frequent occurrence of pattern whorl than pattern loop and the arches were least occurring pattern on all the digits.

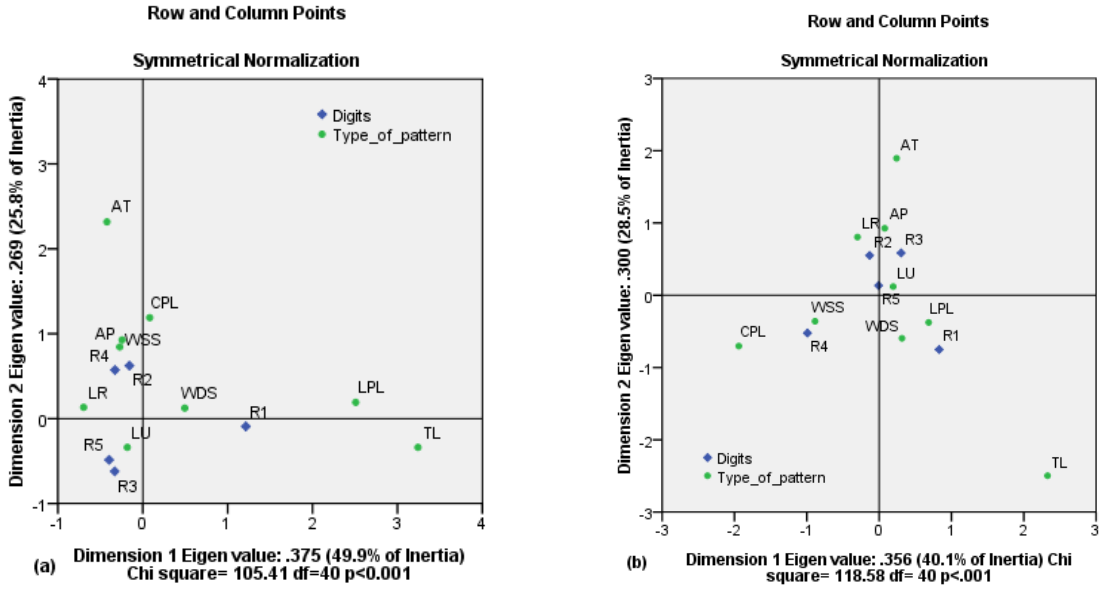

Figure 6. Correspondence analysis between digits of the right hand and different type of patterns (a) convicted female group (b) control female group. R1, Right thumb; R2, Right index finger; R3, Right middle finger; R4, Right ring finger; R5, Right little finger; AP, Arch plain; AT, Arch tented; LR, Loop radial; LU, Loop ulnar; WSS, Whorl single spiral; WDS, Whorl double spiral; LPL, Lateral pocket loop; CPL, Central pocket loop; TL, Twin loop.

Previous literature[27,28] found that the frequency of whorls was higher in sexual offenders when the comparison was made between sexual offenders and common criminals and between sexual offenders and controls respectively. Biswas[29] also observed a greater whorl index in two series of jail convicts and this finding was supported by the reports of Sen[30] and Singh[31]. Correspondence analysis in the present study further strengthened the relationship between whorl pattern and divergent behavior among male cohort group by exhibiting a close association

between thumb and whorl double spiral, but in control group thumb was closely associated with loop ulnar. Greater number of loops among the males in control group also convergent with the findings of Hutchinson[32] which stated that individuals with greater number of loops on index, middle and ring finger have positive characteristics.

Agarwal *et al.*[33] performed a study on prisoners and controls of North Indian hilly population to analyze the difference of behavioral traits among them. In divergence to the present study, they found that the whorls were more frequent in the control population, whereas the frequency of the loops was higher in prisoners. They also noticed that greater number of whorls in the controls showing a positive psychological characteristic. Past literature[12,34,35] delineated a lower frequency of whorls on the digits of the convicts.

An opposite trend was noticed in female convicts of the present study where the percentage of ulnar loops was higher than their control counterparts. A dermatoglyphic patterns of female convicted criminals of Anambra state was studied by Pricilla *et al*.[36] and they noticed the frequency of loops was higher in controls than criminals. In the present study it was also observed that the frequency of radial loops was higher among the male convicted prisoners, whereas in females the radial loops were present mostly in the controls.

The dermatoglyphic patterns of 15 violent criminals and 15 sexual offenders were investigated by Karim *et al*.[28] to explore the distribution of dermatoglyphic patterns and observed that pattern arch was totally absent in criminals. In accordance with this study our findings also witnessed that the arches were least occurring patterns in the convicted prisoners and the frequency of arches was totally absent on digit IV and V of left hand and on digit I and digit V of right hand of the male convicted prisoners. In the present study, the index fingers of male controls exhibited higher overall frequency of the arches than other fingers and in the female control group almost equal frequency of arches was noticed on the index finger as well as on middle finger. This result was convergent with the findings of Hutchinson[32].

The present study demonstrated that the overall frequency of composites was higher in both male and female convicted prisoners than their control counterparts. Similar findings were also witnessed by Karim *et al*.[28] in their study on criminals and found that the prevalence of double and radial loop was higher in the left and right hand of the criminals.

Despite of immense importance in forensic and legal investigations, one of the major limitations of the study is that social, as well as environmental factors contributing to foster antisocial traits were not taken into consideration. Past literature[37,38] on this domain mainly highlighted on the socio-cultural influences on the anti-social behaviour, whereas recent studies[7,8] have identified the possible contribution of biological, genetic and evolutionary factors in the progression of violent behavior. Owing to the up surge in the number of crimes, there is a need for such studies to early diagnosis of the persons risking to commit offences.

In conclusion, the findings of this study indicate to a positive correlation between pattern whorl and criminal behavior, whereas simpler pattern like pattern arch is associated with the control group. Hence further cross-sectional studies using finger as well as palm prints are needed to establish dermatoglyphics as a potential extracranial marker of criminal behavior of an individual.

Ethical approval and consent to participate

Ethical approval was obtained from the Institutional Ethics Committee of Panjab University (PUIEC/2018/144/A-1/29/10 dated 06/12/18) and the purpose of the study was explained to the participants before the commencement of the study.

Declarations of interest

The authors report there are no competing interests to declare.

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