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Sexual variation in the inter-triradial distance of the palm among Bengali Hindu population of Kolkata, India

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Abstract: Palm prints are one of the most important forensic tools for human identification in medico-legal investigation. Palm prints are often used for forensic sex estimation to narrow down the pool of suspects through a process of elimination. The aim of this study was to test whether a novel approach of sex estimation from palmar inter-triradial distances previously posited by Badiye and colleagues [Journal of Forensic and Legal Medicine, 2019; 65(March):22–26] can be used as a primary tool for forensic sexing. For this study the bilateral palm prints from 200 Bengali Hindu adults (100 male, 100 female) were collected using traditional ink printing method and were analysed. Descriptive statistics were presented in tables and linear discriminant analysis was conducted to estimate the extent of sexual dimorphism in the inter-triradial distances and to find out variables with the strongest sex discriminating potential. Binary logistic regression analysis (BLR) was performed to derive sex estimation equations. Sexual dimorphism has been found to be statistically significant ($p < 0.001$) using linear discriminant analysis with a sexing accuracy of 79.0 percent for the left and 79.5 percent for the right palm. Distance between a and t triradius has been found to be the most influential on this model followed by the combined abcd-t distance. For the BLR analysis, the correct classification percentage was found to be the highest on the a-t distance of the right palm with a success rate of 80.5 percent which is closely followed by the combined abcd-t distance which has a classification success rate of 80.0 percent for the right palm. The present study has concluded that, inter-triradial distance of the palm is fairly dimorphic sexually but can only be used as a supplementary tool in inference of sex for medico-legal investigation. Due to a higher accuracy, the distance between a and t triradius has been proposed to be used instead of combined abcd-t distance which was suggested in the original study conducted by Badiye and colleagues (2019).

Key words: Forensic Anthropology, Palm Print, Triradii, Sex Estimation, Discriminant Function Analysis, Dermatoglyphics.

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Introduction

Palm is the ventral surface of hand that is anatomically located in between the base of fingers and the wrist. Latent palm print is the impression left by the palmar epidermal ridges on a surface and is one of the most important means for the determination of individuality in forensic investigation (Christofidis et al. 2018). In almost thirty percent of cases where dermatoglyphic prints are recovered from different surfaces, they are from the palm according to a previous study (Jain and Feng 2009). Such surfaces can include gun grips, knife or sword haft, steering wheels of vehicles, door handles, computer mouse and smartphones (Christofidis et al. 2018).

The palm is divided into thenar, hypothenar and interdigital areas by principal lines on the volar pad (Badiye et al. 2019). Epidermal ridges on palm are formed between 6th and 16th week of gestation period (Gutiérrez-Redomero and Alonso-Rodríguez 2013). Anatomical landmarks of palm are determined by the presence of triradii Palmar triradius is a Y shaped landmark formed by a group of three epidermal papillary ridges of the palm. There are four interdigital triradii-located at the base of each finger and one axial triradius located proximal to the wrist (Krishan et al. 2014).

Interindividual, population and sexual variation of epidermal ridges on the palmar surface along with its disease associations has long been studied and reported by various scholars in the past (Meier 1980; Schaumann and Meier 1989; Bhat et al. 2014; Dorjee et al. 2014; Singh et al. 2016). Sexual variation in the palmar ridge patterns has also been widely studied in the context of forensic dermatoglyphics. Sexual dimorphism previously observed in the Mean Ridge Breadth (David 1981), epidermal palmar ridge breadth (Cummins et al. 1941; Ohler and Cummins 1942) and palm print ridge density (Krishan et al. 2014) can be used as a potential tool for forensic sexing. Recently Badiye et al. (2019) has presented a novel approach of sex determination using the distance between interdigital and axial triradii of palm among a heterogenous population of central India (Badiye et al. 2019). The present study has attempted to validate the measurements described by Badiye et al. (2019) on a sample of Bengali Hindu adults with the intention to test if the novel approach taken by Badiye et al. (2019) can reliably be used for sex estimation in medico legal context and also have provided a discussion in light of the previous literature.

Materials and methods

Study area and people

A group of 200 adult individuals (100 males and 100 females) of Bengali Hindu origin were randomly chosen from the city of Kolkata, India for this study with informed consent. Sample size was kept in line with the previous study conducted by Badiye et al. (2019). Subjects chosen were all healthy, without any congenital deformity, burn and injury, amputations, surgical marks in the palm. Subjects with a missing c triradius at the base of the fourth digit were excluded from the study since the c-t distance is required for analysis. The purpose of the study along with their rights according to the ethical standards of human experiments as laid down in the Helsinki Declaration were clearly explained to all participants.

Method

Palm prints of all the study participants were collected using traditional ink printing method as described by Cumins and Midlo (Cummins and Midlo 1926). First the participants were asked to clean their hands with soap and water and dried their hands with a clean towel. Then a clean plain glass plate of 15 x 15 cm size was smeared with Kores black ink with the help of a roller to get a uniformly coated thin film of ink on the surface of the sheet. The ink was then applied to the palm of each participant by placing the palmar surface on the inked glass plate and gently pressing the dorsal surface of the hand against the plate. Care was taken so that the hollow of the palm and the flexor creases of the wrist get uniformly coated with ink without any appearance of a smudge. Following this procedure, the inked hands were pressed against a plain piece of white paper sheet (placed on a flat table) from proximal to distal direction. Finally, the hand was lifted from the paper from distal to proximal end leaving a clear impression of the whole palm. Same procedure was repeated for both right and left hands. Participant's age and sex were also recorded while taking the palm prints.

After the palm prints were taken, they were used for dermatoglyphic analysis using a handheld magnifying glass. All four triradii located at the base of second, third, fourth and fifth digits were identified and were labeled as 'a', 'b', 'c', and 'd' triradius respectively. The axial triradius proximal to the wrist was labeled as 't' triradius. Distances between a-t, b-t, c-t, and d-t were measured using a scale. Combined abcd-t distance was calculated by summing up a-t, b-t, c-t, and d-t distances. All readings were recorded for further statistical analysis.

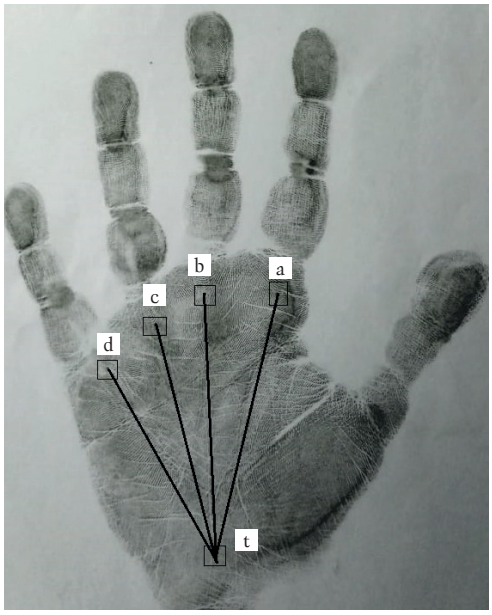
Statistical analysis

The data obtained were analysed using IBM SPSS statistics software version 27.0, Chicago, Illinois, USA. The descriptive statistics of a-t, b-t, c-t, d-t, and combined abcd-t distance of both hands for male and female has been presented in tabular form. Discriminant function analysis was used to visualize the degree of overlap between males and females and to identify the variables with strongest sex discriminating potential. The extent of sexual dimorphism has also been described using Wilks' lambda values with a scale ranging between 0 and 1, where 0 indicates total discrimination and 1 indicates no discrimination. Finally, Binary Logistic Regression analysis with a classification cutoff set as 0.5 was performed to derive sex estimation equations from inter triradial distances mentioned above for both hands.

Inter and Intra observer error

Inter and intra observer error in the measurement of a-t distance on the left palm was quantified by RB and MD before commencement of the study by taking both impression of the palm as well as the measurement in 30 randomly selected participants (pooled sex). Systematic error of measurement was measured using the paired t-test while the random error was measured using Technical Error in Measurement (TEM). Absolute TEM was calculated using the standard formula $TEM = \sqrt{(\sum D^2/2N)}$, where D is the deviations between measurements, and N is the number of individuals measured (Perini et al. 2005). Relative TEM was then calculated using the formula %TEM= (TEM/VAV) x100, where % TEM is the TEM expressed as percentage, and VAV is the Variable

Average Value (Perini et al. 2005). RB and MD have tested for inter observer error in measurements while MD has tested for intra observer error in measurements within a gap of a few days. No significant inter (t= -0.812, df= 29, p= 0.423) as well as intra (t= -0.571, df= 29, p= 0.573) observer error was found for the a-t distance on left palm using the paired t-test. The relative TEMs for inter and intra examiners for the same repeated a-t distance measurement on the left palm were 0.04 percent and 0.06 percent respectively, and are well below the accepted 5 percent mark (Rajaah et al. 2010). The results indicate that the measurements are reproducible without any significant error.



Legends: a - Triradius 'a'; b - Triradius 'b'; c - Triradius 'c'; d - Triradius 'd'; t - Triradius 't'

Fig. 1. Left palmprint showing five palmar triradii namely a, b, c, d, t and inter-triradial distances in between (fig: Field source)

Results

Descriptive statistics for all variables have been presented in the Table 1 and the result of linear discriminant analysis along with its correct classification accuracy has been presented in the Table 2, for both left and right palm. Overall 79.0 percent accuracy has been achieved for the left palm and 79.5 percent accuracy has been achieved for the right palm. 78 percent males and 80 percent females were correctly classified from left palm prints, while 77 percent males and 82 percent females were correctly classified from right palm prints. Table 3 has presented Wilks' lambda values which are 0.598 and 0.568 for the left and right palms respectively. Wilks' lambda values indicate that the difference between males and females in terms of the inter triradial distance is statistically significant ($p<0.001$) for all the variables analyzed in the present study. Table 4 has presented the structure matrix for left and right palm and it has been observed that a-t distance has the greatest sex discriminating potential followed by the combined abcd-t distance. Finally, the result of Binary Logistic Regression analysis along with its correct classification percentage for each variable has been presented in the Table 5 for both left and right palm. For the right palm, the highest classification success rate of 80.5 percent was found for the a-t distance, which is closely followed by the combined abcd-t distance for which the correct classification percentage was 80.0 percent. The classification success rate for logistic equations was found to be slightly lower for the left palm, where the correct classification percentages achieved were 78 percent and 77 percent for the a-t and combined abcd-t distance respectively.

Table 1. Descriptive Statistics for left and right palms

Descriptive statistics for left palms					
	Sex	*n*	Mean (cm)	Std. Deviation	Std. Error
a-t	Male	100	8.29	0.60	0.06
	Female	100	7.30	0.64	0.06
b-t	Male	100	8.47	0.63	0.06
	Female	100	7.49	0.73	0.07
c-t	Male	100	8.04	0.62	0.06
	Female	100	7.08	0.70	0.07
d-t	Male	100	7.24	0.61	0.06
	Female	100	6.35	0.68	0.06
abcd-t	Male	100	32.05	2.37	0.23
	Female	100	28.23	2.69	0.26
Descriptive statistics for right palms					
	Sex	*n*	Mean (cm)	Std. Deviation	Std. Error
a-t	Male	100	8.28	0.56	0.05
	Female	100	7.35	0.54	0.05
b-t	Male	100	8.43	0.57	0.05
	Female	100	7.53	0.63	0.06
c-t	Male	100	8.03	0.53	0.05
	Female	100	7.16	0.65	0.06
d-t	Male	100	7.22	0.57	0.05
	Female	100	6.44	0.63	0.06
abcd-t	Male	100	31.98	2.12	0.21
	Female	100	28.49	2.39	0.23

Table 2. Classification results for left and right palm. 79.0% of original grouped cases correctly classified for left palm and 79.5% of original grouped cases correctly classified for right palm

Result of linear discriminant analysis for left palms					
		Sex	Predicted group membership		Total
			Female	Male	
Original	Count	Female	80	20	100
		Male	22	78	100
Result of linear discriminant analysis for right palms					
		Sex	Predicted group membership		Total
			Female	Male	
Original	Count	Female	82	18	100
		Male	23	77	100

Table 3. Wilks′ lambda value for left and right palms, indicating a significant difference between males and females

Wilks′ lambda for left palms				
Test of function(s)	Wilks′ lambda	Chi-squared	df	Sig.
1	0.59	100.80	4	$p<0.001$
Wilks′ lambda for right palms				
Test of function(s)	Wilks′ lambda	Chi-squared	df	Sig.
1	0.56	110.85	4	$p<0.001$

Table 4. Structure matrix listing variable influence on the model for left and right palms

Structure matrix for left palms	
Function 1	
a-t	0.97
abcd-t	0.92
c-t	0.88
b-t	0.87
d-t	0.83
Structure matrix for right palms	
Function 1	
a-t	0.97
abcd-t	0.89
b-t	0.86
c-t	0.84
d-t	0.74

Table 5. Result of binary logistic regression analysis for left and right palms

Result of binary logistic regression analysis for left palms			
Variables	Regression model	Correct classification percentage	Wald
a-t	-21.187+2.707(a-t)	78.0	47.76
b-t	-18.741+2.337(b-t)	74.5	44.58
c-t	-18.218+2.399(c-t)	73.0	45.56
d-t	-15.738+2.306(d-t)	72.5	44.21
abcd-t	-20.263+0.669(abcd-t)	77.0	45.57
Result of binary logistic regression analysis for right palms			
Variables	Regression model	Correct classification percentage	Wald
a-t	-28.230+3.610(a-t)	80.5	47.86
b-t	-21.797+2.721(b-t)	74.5	46.61
c-t	-21.059+2.756(c-t)	78.0	46.35
d-t	-15.834+2.307(d-t)	75.5	43.40
abcd-t	-23.516+0.775(abct-t)	80.0	47.67

Discussion

The observed difference between males and females with respect to the inter triradial distance is largely attributable to the fact that male hands are larger than female hands on an average (Kanchan and Krishan 2011) leaving a larger palmar area for males. The novel approach taken by Badiye et al. (2019) was applied to 65 males and 63 females and sexual dimorphism was reported to be statistically significant at $p < 0.01$ level (Badiye et al. 2019). They have suggested that a combined abcd-t distance of less than or equal to 30 cm will more likely to be of a female, and greater than or equal to 32.5 cm will more likely be of a male. It has been observed in the present study that the a-t distance has a higher sexing accuracy than combined abcd-t distance. Therefore, it is proposed that instead of taking the combined abcd-t distance (as has been suggested by Badiye et al. 2019), the a-t distance may be of better use since it has the most influence on this model.

In a similar study conducted by Jerković et al. (2023) on 119 left palmprints (66 males and 53 females) and 134 right palmprints (73 males and 61 females) reported sexing accuracy lied between 64 and 85 percent for univariate model and between 81 and 87 percent for multivariate model with the sexual dimorphism being statistically significant at $p < 0.001$ level (Jerković et al. 2023). Although Badiye et al. (2019) did not report the sexing accuracy of their novel technique, we report a sexing accuracy of 79.0 percent on the left palm and 79.5 percent on the right palm for LDA, and 80.5 percent for the logistic equation of the a-t distance on the right palm by using their technique. It has also been observed that the percentage success for correct classification using this technique is marginally greater for the logistic regression analysis of a-t and combined abcd-t measurements of the right palm than the linear discriminant analysis. Traditionally, the reference guide for classifying the accuracy of a test is considered in the following way: fail test (0.50–0.60), poor test (0.60–0.75), fair test (0.75–0.90), good test (0.90–0.97), and excellent test (0.97–1.00) (Krishan et al. 2014). Based on this traditional reference guide we conclude that the novel approach taken by Badiye et al. (2019) is only a fair test and it can only be used as a supplementary tool in inference of sex from palm prints recovered from a crime scene.

Conclusion

In conclusion, forensic sex estimation from palm prints remains a challenge, but this study has validated the inter-triradial distances between 'a', 'b', 'c', 'd', and 't' triradii as a potential supplementary tool for forensic sexing of palm prints. The a-t distance has been identified as producing the most accurate results in sex estimation. Binary Logistic Regression models have been presented for a-t, b-t, c-t, d-t, and combined abcd-t distances, which can be used to predict sex. However, future studies are needed to further investigate the influence of the combined abcd-t distance on this model for different populations. Moreover, future research should focus on investigating sexual variation in subadult individuals and the exact age of full expression of these inter-triradial distances. Further exploration should also be carried out to estimate stature and other body dimensions from palmar

inter-triradial distances, opening new avenues for human identification in medico-legal contexts. Overall, the findings of this study provide valuable insights for forensic experts and legal authorities in identifying individuals through palm prints.

List of abbreviations

SPSS – Statistical Package for Social Sciences
IBM – International Business Machine

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Ethics approval and consent to participate

Verbally informed consent was obtained from participants prior to conducting the study, Ethics committee approval was not required. Written informed consent was not taken.

Conflict of interest

The authors declare that there is no conflict of interests.

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Authors' contribution

RB – project design, statistical analysis and report writing
MD – Fieldwork and data collection, data extraction, tabulation

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