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Sex estimation using palmprint measurements among a sample of adult Egyptians

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Abstract
Aim: Sex estimation is crucial in the forensic field. Palmprints are unique prints that are commonly recovered from crime scenes. A tri-radius 'delta' is a meeting point of three groups of ridges. Five tri-radii are identified on the palm, four at the base of Index (a), Middle (b), Ring (c) and little finger (d), and one axial tri-radius (t) near the wrist. This study assessed the validity of distance between palmar tri-radii (abcd-t) as a sex predictor in a sample of Egyptians.
Material and Methods: The study was conducted on 100 adult Egyptians (50 females and 50 males). Palmprints were obtained using fingerprint inked strips (6 x 10 inches). Palmprints were scanned and the distances between the axial tri-radius 't' and other tri-radii (a, b, c, and d) were measured using Software. Also, combined abcd-t distance (sum of four distances) was calculated.
Results: Means of palmar tri-radii distances from (abcd) to axial t were significantly higher in males. ROC curve analysis was done for all palmar tri-radii distances. Male could be predicted on the right side when (d-t) distance >7.11cm or combined abcd-t distance > 32.17 cm with accuracy (88%). On the left side, male could be predicted when (b-t) distance> 8.65 cm or combined abcd-t distance>32.37 cm with accuracy (87%).
Discussion: Palmar tri-radii distances are significantly longer in Egyptian males. Subsequently, these measurements could predict sex with reasonable accuracies among adult Egyptians. Similar studies on other populations are recommended.

Keywords
Sex Estimation, Palmprint Measurements, Palmar Tri-Radii Distances, Egyptians

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Introduction

Identification is important not only in legal medicine but also in criminal investigations and genetic research [1]. Dermatoglyphics is one of the reliable methods that can be used in medicolegal identification [2].

Dermatoglyphic traits refer to epidermal ridges and furrows on the fingers, palms, soles, and toes. The embryogenesis of the ridges is influenced by certain genes. Also, the intrauterine environment, such as the amniotic fluid content during the 10th to 16th week of intrauterine life, may affect ridge formation [3,4].

The palmprint is the print of the inner aspect of the hand from the base of fingers to the wrist joint. Three principal lines divide the palm into three parts: thenar (adjacent to the thumb), hypothenar (adjacent to the little finger), and inter-digital areas (adjacent to the base of fingers) [5,6].

Palmprints have many unique characteristics as fingerprints. However, palmprints have a significantly wider surface area in relation to fingerprints. Also, palmprints have additional distinguishing features such as principal lines and creases. Palmprints account for about 30% of the latent prints recovered from crime scenes. Subsequently, there is an escalating need for palmprints databases worldwide [7-9].

A tri-radius (also known as 'delta') is defined as a point at which three groups of ridges from three directions meet at angles of approximately 120° [10]. Generally, there are five tri-radii on the palm, four are located in the inter-digital areas at the base fingers {Index (a), Middle (b), Ring (c) and little finger (d)}, and one is located near the wrist, which is termed as axial tri-radius (t). In dermatoglyphic researches, the position of the tri-radii of the palms acts as a crucial landmark [11,12]

The application of distances between tri-radii (abcd-t) of the palm for sex determination is investigated only in the central Indian population [13]. It is important to consider that palmprint's features are population specific. Thus, there is a necessity to evaluate the utility of distances between palmar tri-radii as a sex predictor in different populations. The current study aimed to assess the validity of the distance between palmar tri-radii (abcd-t) as a sex predictor in a sample of adult Egyptians.

Material and Methods

The current study was carried out in the Department of Forensic Medicine and Clinical Toxicology, Faculty of Medicine, Alexandria University, Egypt. This cross-sectional study was conducted on one hundred Egyptians (50 females and 50 males) aged between 18-and 30 years. The Ethics Committee of Alexandria, Faculty of Medicine approved the current study (FWA number: 00018699, IRB number: 00012098, approval serial number: 0201360), also informed consent was obtained from all participants.

Subjects with inflammation or injuries on the palm were excluded from the study. Any cases with physical abnormality due to fracture, amputation, burn, congenital deformity, or deformity due to surgical procedure were also excluded.

The following materials were utilized: 6 x 10 inches Fingerprint Inked Strips (New York-USA), which are composed of a fine layer of ink coated between two thin flexible plastic sheets, A4 white paper, soap, and dry towels.

The demographic data of each participant were recorded, including age, sex, and nationality. Then, the inked palmprint was obtained.

1. Obtaining inked palmprint: [13,14]

• Each participant was asked to wash both hands with soap and water.

• The fingerprint inked strips were pulled apart to reveal the inked layer.

• The palm was placed on these opened strips and the dorsum of the hand pressed forcibly to flatten the palm and open the creases.

• The inked hands were pressed firmly on white paper from the proximal to distal direction.

• The palms lifted away from the paper in opposite direction from the distal to the proximal end.

2. Examination and analysis of palmprints: [13,15]

The inked palmprints were scanned with resolution of 600 dots per inch (dpi) and analyzed using software (CorelDRAW 2020).

Figure 1 illustrates an inked palmprint with five Palmar tri-radii:

• Tri-radius at the base of the Index finger 'a'

• Tri-radius at the base of the Middle finger 'b'

• Tri-radius at the base of the Ring finger 'c'

• Tri-radius at the base of the little finger 'd'

• Axial tri-radius at the base of the fourth metacarpal near the proximal end of the palm and near the wrist 't'.

The distances of the tri-radii a, b, c, and d from the axial tri-radius 't' were measured using a ruler tool. The combined abcd-t distance, which is the sum of the four distances (a-t + b-t + c-t + d-t) was calculated for each palm in all participants.

Statistical Analysis:

The IBM SPSS software package version 25.0 was used to analyze the data. The Kolmogorov-Smirnov test was employed to ensure the normality of the distribution. The student t-test was used for normally distributed quantitative variables, to compare two studied groups. The receiver operator characteristic (ROC) curve analysis was used to detect the cutoff values for sex prediction using distances between palmar tri-radii. The area under the ROC curve (AUC) was used to determine the accuracy.

Results

The study was conducted on 100 adult Egyptians (50 males and 50 females). The age of the participants ranged from 18 and 30 years. The mean age of males was 22.4±2.8 years, while that of females 22.5±3.1years. There was no statistically significant difference in age between males and females (p =0.595).

Inked palmprints were obtained and analyzed by two forensic experts. For the inter-observer reliability, the intra-class correlation coefficient (ICC) value was exceeding 0.9, which indicates excellent reliability. The repeatability of the measurements for the same observer (intra-observer agreement) also exceeded 0.9.

Table 1 reveals the measurement of distances from the interdigital tri-radii 'a, b, c, d' to axial tri-radius 't' (a-t, b-t, c-t, d-t) in palmprints of both sexes. All measured palmprint tri-radii distances (a-t, b-t, c-t, d-t) were statistically higher in males with p<0.001.

Figure 2 (a, b) shows the comparison between males and females regarding the frequency of combined abcd-t distances on right and left palms.

• On the right palmprint, the highest frequency of combined abcd-t distance in males was in the range of 32.5-34.9 cm, representing 42% of the studied males. Meanwhile, in females' right palm the highest frequency was in the range of 27.5-29.9 cm, representing 44% of the studied females.

• On the left palmprint, the most common frequency of combined abcd-t distance in males was in the range of 32.5-34.9 cm, representing 44% of the studied males. Meanwhile, in females' left palm, the highest frequency was in the range of 30-32.4 cm, representing 46% of the studied females.

Table 2 and Figure 3 (a, b) demonstrate ROC curve analysis for palmar tri-radii distances and combined abcd-t distance on right and left palmprints.

• On the right palmprint, sex could be predicted with accuracies ranging from 80% to 88%. The best accuracy was at (d-t) distance and the combined abcd-t distance with 88% accuracy for each. Regarding (d-t) distance the cut-off point for male sex prediction was >7. 11cm (sensitivity 94%, specificity 82%, P<0.001, AUC=0.944) and for the combined abcd-t distance was >32.17cm (sensitivity 90%, specificity 84%, P<0.001, AUC=0.949).

• On the left palmprint, sex could be predicted with accuracies ranging from 83 % to 87%. The best accuracy was at the (b-t)



Figure 1. Measurements of palmar tri-radii distances from a, b, c, and d to axial t.

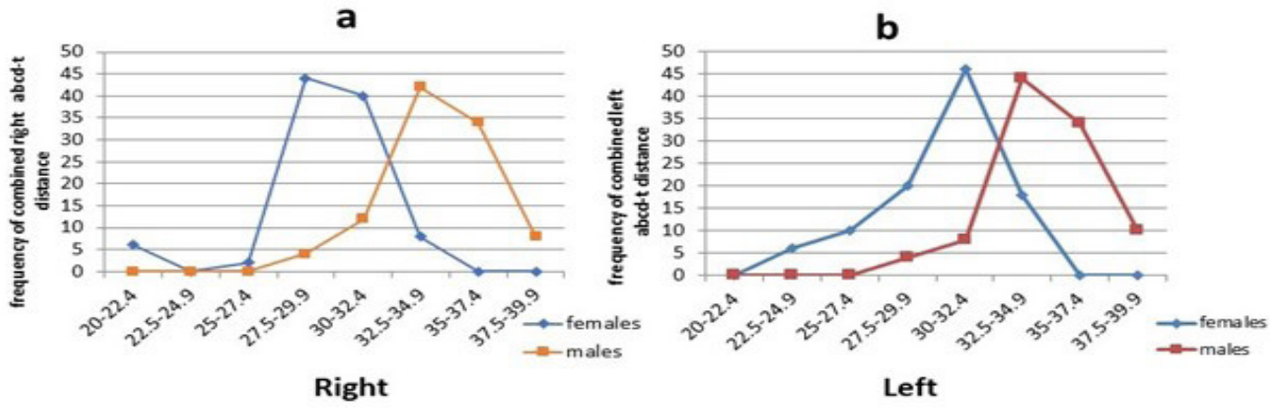

Figure 2. The frequency of combined abcd-t distance of males and females on the right side (2a) and left side (2b).

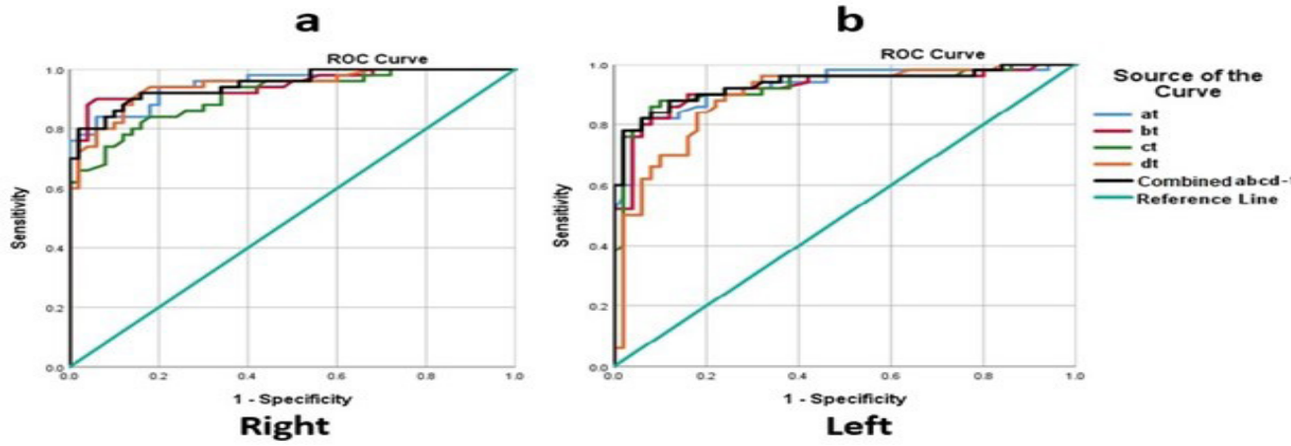

Figure 3. ROC curve for the performance of palmar tri-radii distances in prediction of sex on the right side (3a) and left side (3b).

Table 1. Descriptive statistics of the palmprint measurements in Egyptian males and females on both sides

Gender		Right hand				Left hand			
		a-t (cm)	b-t(cm)	c-t(cm)	d-t(cm)	a-t(cm)	b-t(cm)	c-t(cm)	d-t(cm)
Males	Mean±SD	9.0 ±0.56	9.24±0.60	8.71±0.67	7.83±0.54	8.96±0.60	9.23±0.61	8.77±0.60	7.77±0.52
	Min-Max	7.62-10.42	7.82-10.75	7.24-10.21	6.32-8.69	6.86-10.0	7.23-10.52	6.97-10.04	6.02-8.69
Females	Mean±SD	7.75±0.58	7.94±0.69	7.49±0.72	6.52±0.68	7.89±0.54	8.12±0.69	7.55±0.73	6.70±0.74
	Min-Max	6.12-8.56	5.78-9.09	5.30-8.55	4.68-7.72	6.55-8.79	6.24-9.14	5.49-8.87	4.90-8.62
t- test		10.941	9.964	8.733	10.614	9.218	8.454	9.086	8.274
p-value		<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

a-t: Distance between tri-radius a and axial t, b-t: Distance between tri-radius b and axial t, c-t: Distance between tri-radius c and axial t, a-d: Distance between tri-radius d and axial t, SD =standard deviation, *p-value significant at level <0.05

Table 2. ROC curve analysis for different palmar tri-radii distances (a-t, b-t, c-t, d-t and combined abcd-t) as sex predictors

	Cutoff point (cm)	AUC	P-value	Sensitivity	Specificity	Accuracy
Right hand						
a-t	8.23	0.950	<0.001*	90.0%	80.0%	85.0%
b-t	8.48	0.946	<0.001*	92.0%	80.0%	86.0%
c-t	7.79	0.912	<0.001*	94.0%	66.0%	80.0%
d-t	7.11	0.944	<0.001*	94.0%	82.0%	88.0%
Combined abcd-t	32.17	0.949	<0.001*	90.0%	84.0%	88.0%
Left hand						
a-t	8.38	0.926	<0.001*	90.0%	80.0%	85.0%
b-t	8.65	0.919	<0.001*	90.0%	84.0%	87.0%
c-t	8.14	0.927	<0.001*	90.0%	80.0%	85.0%
d-t	7.23	0.893	<0.001*	90.0%	76.0%	83.0%
Combined abcd-t	32.37	0.933	<0.001*	90.0%	82.0%	87.0%

*p-value significant at level <0.05, Cutoff point for male gender prediction

distance and the combined abcd-t distance with 87% accuracy for each. Regarding (b-t) distance, male sex was predicted at a cut-off point > 8.65 cm (sensitivity 90%, specificity 84%, P<0.001, AUC=0.919) and for the combined abcd-t, distance was >32.37 cm (sensitivity 90%, specificity 82%, P<0.001, AUC=0.933)

Discussion

Sex estimation is one of the most challenging tasks in forensic practice. Dermatoglyphics is frequently used to provide evidence about sex [16]. Other than medicolegal purposes, literature linked palmar dermatoglyphics with certain medical conditions like idiopathic epilepsy [17], and coronary artery disease [18].

In forensic practice, palmprints have been utilized to distinguish different populations because of ethnic variance [19]. Also, different palmprint features were extensively investigated as sex predictors, such as ridge density [9] and palmprint measurements [20-21]. However, to date, there are limited data regarding the use of palmar tri-radii (abcd-t) distances as a sex predictor [13]. The present study investigated for the first time the use of these distances (abcd-t) for sex identification in the Egyptian population.

The current study was conducted on 100 Egyptians aged 18 to 30 years. Eighteen years was selected as a lower limit to ensure a well-established sexual dimorphism, above this age, the significant differences between both sexes regarding prints have been settled [22]. In this study, individuals above the age of thirty years were excluded to avoid the age-related changes on palmprints, especially the position of palmar tri-radii [15,23]. The current study used Fingerprint Inked Strips because they produce clear crisp permanent palmprints without over-inking due to the thin layer of ink coated on the strips. These inked strips are simply used with minimal hygiene or cross-infection risks. Also, they are non-toxic with no reported hypersensitivity [24]. Their reasonable price makes Inked Strips convenient, especially in developing countries including Egypt. The obtained palmprints in the current study were scanned and palmar tri-radii distances (abcd-t) were measured accurately using specialized software [15]. Badiye et al. in 2019 [13] studied inked palmprints directly under a hand-illuminated microscope, and the distances were measured using a scale. However, the method used in this study is less time-consuming and relatively more accurate than the method used by Badiye et al. in 2019.

Intra-observer and inter-observer agreements were excellent, indicating reliability and objectivity of the obtained palmar measurements. In the present research, the means of all palmprint tri-radii distances (a-t, b-t, c-t, d-t) were significantly higher in males than females, which agrees with Badiye et al. who conducted their study on the central India population in 2019 [13].

Regarding males, the highest frequency of combined abcd-t distance was 32.5-34.9 cm, representing 42% and 44% of the studied males on the right and left sides, respectively. This coincides with the results reported by Badiye et al. in 2019 [13]

where the highest frequency of combined abcd-t distance was 32.5-34.9 cm, representing 41,5% and 32,3 % of the studied males on the right and left sides, respectively.

Regards females, on the right palm, the highest frequency was 27.5-29.9 cm, representing 44%, but on the left palm, the highest frequency was 30-32.4 cm, representing 46% of the studied females. Whereas Badiye et al who studied a population of central India stated that the commonest frequency of combined abcd-t distance on the right side was 30-32.4 cm, representing 33,3% and 27.5-29.9 cm on the left side, representing 36.5% of the studied females [13]. Population-related variation could explain the inconsistency between the current results and that of Badiye et al. (2019) regarding combined palmar tri-radii distances in females [15].

In the present work, ROC curve analysis was implemented to allow the practical applicability of the results. Sex could be predicted with an accuracy ranging from 80% to 88% on the right side with the best accuracies using d-t or combined abcd-t distance. Whereas on the left side, the accuracy ranged from and from 83 % to 87% with best accuracies using d-t or combined abcd-t distance.

Badiye et al. (2019) is the only previous study that investigated the utility of palmar tri-radii (abcd-t) distances. They analyzed their results in the Indian population using a probability test rather than a more applicable ROC curve analysis that challenges the comparability of their results with that of the present study. However, Badiye et al. (2019) pointed to the potential utility of palmar tri-radii distances in sex identification among Indians [13].

Different palmprint parameters had been previously used for sex prediction other than palmar tri-radii (abcd-t) distances, such as palmprint measurements, ridge density, and palmar digital intertriradial distances [9,15,20,21]. Ishak et al. 2012 [20] denoted that palmprints measurements could be used in sex prediction along with other hand dimensions in an Australian population. Also, Kolić et al. 2020 [21] proved that palmprint measurements could identify sex in the Croatian population. Considering palmprint ridge density, Krishan et al. 2014 [9] correctly identified the sex of the North Indians with 66.8% and 71.7% accuracies on right and left sides, respectively. Regarding the palmar digital intertriradial distances, Jerković et al. 2021 [15] claimed that the accuracy of using these measurements in both hands reached 87% in the Croatian population.

In crime scenes, the palmprint is not usually complete to the extent that allows obtaining whole palmprint dimensions. In such situations, the palmar tri-radii distances could be applied for sex identification with high accuracy. Also, measuring the distances between palmar tri-radii (abcd-t) is much easier than counting palmprint ridge density, where placing, orientating squares, and counting the ridges is difficult and time-consuming. However, it is important to consider that palmprint features, including palmar tri-radii, are affected by palmprint quality and persistence in the scene.

In mass casualties, the distances between palmar tri-radii could be used to identify the sex of the mutilated corpses as long as the palmprints are obtainable. On the other hand, in advanced decomposition and extensive mutilation, obtaining palmprints is impossible, which necessitates the use of other identification methods. In general, DNA analysis is the most precise method for identification. DNA could be extracted from any available tissue, even if the decay was advanced, however, complex analysis procedures along with high cost limit its utility [25].

Conclusion and Recommendations

The current study pointed to palmar tri-radii distances (abcd-t) as a valuable and convenient sex predictor with reasonable accuracies among adult Egyptians. This method could be used for sex prediction in mass disasters where the number of unidentified victims is large and also for sex identification of persons leaving their palmprints at the scene. Further studies on palmar tri-radii distances are recommended using larger samples in Egyptians. Similar studies are needed to verify the utility of palmar tri-radii distances in different populations. Also, other palmprints features such as handprint measurements and ridge density could be studied along with palmar tri-radii distances to further enhance the accuracy of sex identification.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

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