Sex differences in fingerprint ridge density among Maldivian and Bangladeshi populations

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Abstract

Fingerprinting has been the traditional method for human identification in criminal investigations due to its unique discriminatory power. The objective of this study is to establish any difference in mean ridge density of fingerprints between Maldivian and Bangladeshi men also see the difference in fingerprint ridge density between Maldivian male and female population. Variability in ridge density was studied by counting ridges in the radial and ulnar regions of fingerprints by counting diagonally on ridge counting/25 mm². One hundred ten-print cards from these population groups in the age range 18 - 60 were obtained from the fingerprint database of Maldives Police Service. In comparing Maldivian male and female, the statistical analysis showed that ridge density $\leq$ 14 ridges/25 mm² would more likely originate from a male, and a ridge density $\geq$ 15 ridges/25 mm² would indicate a potential Maldivian female in both areas of both hands. In comparing Maldivian male and Bangladeshi male, the statistical analysis showed that in radial area, ridge density $\leq$ 13 ridges/25 mm² were more likely to originate from a Bangladeshi male, whereas a ridge density $\geq$ 14 would indicate a Maldivian male. In the ulnar area, a ridge density $\geq$ 13 to 16 ridges/25 mm² will indicate a Bangladeshi male respondent.

Keywords: Fingerprint identification, forensic, human identification, ridge density, sex differences

1. Introduction

Fingerprints, also known as friction ridges, are raised portions of the skin's epidermis. They spread over the inner surfaces of palms, fingers (palmar) or soles of the feet (plantar). Friction ridges appear in unique patterns and they allow identification of individuals based on the prints they leave on surfaces. Fingerprint identification process involves comparing unknown friction ridge impressions to known friction ridge impressions to determine if they match [1]. Recent studies highlighted the increased interest for predicting sex from fingerprints in the judicial and scientific fields [2]. Many studies have explored dermatoglyphic traits such as fingerprint ridge density and the epidermal ridge breadth and their variation between different sexes and populations [3]. It has

been established that there can be important differences in fingerprints between the sexes and populations. Sex classification from a fingerprint is an important aspect of human identification. This information may help investigators filter suspects from a crime.

2. Objective of the study

The objective of this study is to establish any difference in mean ridge density of fingerprints between male and female Maldivians; and between Maldivian and Bangladeshi men.

3. Methods

3.1. Samples and research instruments

Three hundred scanned ten-print cards stored in JPG format (100 Maldivian male, 100 Maldivian female and 100 Bangladeshi male) of aged between 18 to 60 years were randomly picked from fingerprint database records of Fingerprint Laboratory of Forensic Services at Maldives Police Service. As the ten-print card images were cropped, individual's personal information was not included in the images received. The Corel Corporation CorelDraw Graphics Suite 2017 software was to analyze the prints. IBM Statistical Package for the Social Sciences (SPSS) version 17, Minitab 19 Statistical Software and Microsoft Office Excel 2010 were used for statistical analysis.

3.2. Analysis of the fingerprints

The ten-print file was imported into CorelDraw Graphics Suite 2017. And a vector object was created by connecting two squares of 5 × 5 mm and a vertical line through the connecting side of the two squares. A horizontal line was drawn at the base of the squares. In each square, a diagonal line was drawn originating from inner corner to opposite corner. The vectors will then be superimposed onto the fingerprint. The point of intersection of the vertical and horizontal lines was positioned on the core of the fingerprint (Figure 1). The ridges on fingerprints were counted diagonally as described by Acree (1999) [4] and modified by Gutiérrez-Redomero et al. (2008) [5]. A number was given to each ten-print card and all fingers were labeled and the ridge count from each finger was then recorded in a sheet accordingly. Ridge counting was performed on radial and ulnar areas from the 10 fingers of each individual in three sample groups.

3.3. Statistical analysis

Mean, median, standard deviation (SD), maximum and minimum values were determined at radial and ulnar areas separately for each sample group. The mean ridge densities of radial and ulnar were then compared within each population to find out any significant difference between two

defined areas. In addition, comparisons of the mean ridge density between Maldivian males and Maldivian females as well as Maldivian males and Bangladeshi males were made. In each case the independent t-test was used to determine any significant differences. The level of significance α is 0.05 for all statistical tests. IBM Statistical Package for the Social Sciences (SPSS) version 17 was used for statistical analysis. The frequency distribution of ridge densities was obtained in both areas and all subject groups. Probability densities, derived from the frequency distribution, were used to calculate the likelihood ratio (LR). This is to obtain the probability of inferring the target population of origin from ridge density values (Gutiérrez-Redomero et al., 2013) [6]. The likelihood ratio was based on odds form of Bayes' theorem (Nayak et al., 2010) [7], where RD is ridge density, MM the Maldivian male, MF the Maldivian female and BM Bangladeshi male. LR was calculated between Maldivian male and Maldivian female as well as Maldivian male and Bangladeshi male by using following formula.

$$\mathrm{LR} = \frac{\text{Probability of observing a given ridge density if Mldivian male (MM).}}{\text{Probability of observing a given ridge density if Mldivian female (MF).}}$$

$$\mathrm{LR} = \frac{\text{Probability of observing a given ridge density if Mldivian male (MM).}}{\text{Probability of observing a given ridge density if Bangladeshi male (BM).}}$$

The value of LR gives the strength of support for one of the hypotheses: MM or MF and MM or BM. Information obtained from both LR and probability calculation was used to show favored odds Bayes' theorem for support of the most likely hypothesis for a given ridge density P(RD|MM) and P(RD|MF) also P(MM|RD) and P(MF|RD) (Gutiérrez-Redomero et al., 2013) [6]. The following formula was used for computing favored odds.

$$\frac{P(MM \mid RD)}{P(MF \mid RD)} = \frac{P(RD \mid MM)}{P(RD \mid MF)} \times \frac{P(MM)}{P(MF)}$$

Where P(MF|RD) = 1- P(MM|RD) and sample size of male equals sample size of female so P(M) = P(F) (Leonard & Hsu, 2001). Microsoft Office Excel 2010 was used for probability density, likelihood ratio and favored odds calculation.

To perform the statistical analysis, fingerprints will be first analyzed to determine the hand of origin. For this, the method used by Singh et al. (2005) [9] will be used to determine hand of origin in whorl pattern fingerprints. And for loop pattern fingerprints, Brazelle (2015) [10] will be used to determine the hand of origin. No study was conducted to determine the hand of origin in arch pattern so for the ach pattern fingerprint hand of origin will not be determine in this study.

4. Results and discussions

Descriptive statistics such as mean, median, maximum, minimum and standard deviation (SD) of ridge density in radial and ulnar areas in both hands combined for all fingers from Maldivian male, Maldivian female and Bangladeshi male were shown in Table 1. By comparing mean fingerprint ridge density of Maldivian male and Maldivian female, it shows that Maldivian female have a significantly higher ridge density in both radial and ulnar area of the fingerprint when compared to Maldivian males and Bangladeshi males. The result obtained in this study show similar trends as previous studies done for the same topic of sex prediction using fingerprint ridge density. Therefore, this study can strengthen the fact that female tend to have higher ridges density compared to male. By applying t-test, the differences in the mean ridge densities within three groups at radial and ulnar areas were found to be statistically significant at p-value < 0.05. Further, fingerprint ridge density is higher in radial area than in ulnar area in all three groups.

Same statistics were analyzed by subdividing the areas in both hand separated for all 3 groups. The results show that in Maldivian male population there is no significant difference between right hand and left hand radial also right hand and left hand ulnar. In Maldivian female and Bangladeshi male population there is no significant difference between right hand and left hand radial but in right hand and left hand ulnar found to be statistically significant at p-value < 0.05. By comparing Maldivian male and Maldivian female, Maldivian male and Bangladeshi male the differences in the ridge densities at radial and ulnar area of both hands combined and both hand separated were found to be statistically significant at p-value < 0.01.

Distribution of fingerprint ridge when both hand combined in radial and ulnar areas was calculated in all 3 groups. It is observed that in Maldivian males the maximum percentage of fingerprint ridge density on radial area was 14 ridges per 25mm² (22%) and ulnar area was 13 ridges per 25mm² (20.2%). In Maldivian females the maximum percentage of fingerprint ridge density on radial area was 15 ridges per 25mm² (19.5%) and ulnar area was 15 ridges per 25mm² (17.9%). In Bangladeshi male population the maximum percentage of fingerprint ridge density in radial and ulnar area were 13 ridges per 25mm² (21.5%) and (22.5%), respectively.

The results of probability densities, likelihood ratios and favored odds in order to make comparisons in mean ridge density of fingerprints between Maldivian male and Bangladeshi male populations for both radial and ulnar areas of both hand separated were shown in Table 2. The results showed that the favored odds of 10 to 13 ridges per 25 mm² in Bangladeshi male right hand radial were higher than those in right hand radial of Maldivian males. On the other hand, the favored odds of 14 to 19 ridges per 25 mm² in Maldivian males were higher than those in Bangladeshi male right hand radial. In right hand ulnar area, the results showed that the favored odds of 10 to 12 and 14 ridges per 25 mm² in Bangladeshi males were higher than those in

Maldivian males. On the other hand, the favored odds of 15 to 19 and 13 ridges per 25 mm² in Maldivian males were higher than those in Bangladeshi males in right hand ulnar.

The results of probability densities, likelihood ratios and favored odds in order to make comparisons in mean ridge density of fingerprints between Maldivian male and Bangladeshi male populations for both radial and ulnar areas of left hand were presented in Table 3. The results showed that the favored odds of 10 to 13 ridges per 25 mm² in Bangladeshi males were higher than those in Maldivian males. On the other hand, the favored odds of 14 to 18 ridges per 25 mm² in Maldivian males were higher than those in Bangladeshi males. The favored odds derived from Bayes' theorem were used to illustrate the posterior probability that the fingerprint ridge density would be originated from Maldivian male or Bangladeshi male in ulnar area of left hand. The results showed that the favored odds of 10,12,13,15 and 19 ridges per 25 mm² in Bangladeshi males were higher than those in Maldivian males. On the other hand, the favored odds of 11,14,16,17 and 18 ridges per 25 mm² in Maldivian males were higher than those in Bangladeshi males.

This study concludes that using Acree's (1999) [4] method for predicting the sex and population, within the context of Maldivian males and females and Bangladeshi men, may be enabled depending on the information obtained from the latent fingerprint at the crime scene. Based on the findings of this study, it is crucial to know whether the print originated from the right or left hands. If this information cannot be deduced from an overall hand print or at least through other crime scene observations, then the accuracy of prediction will be less. Additionally, comparing the fingerprint ridge density between Maldivian male and Bangladeshi male show notable yet low significance in terms of difference. Hence the method may not be entirely discriminatory for either population.

However, the findings of this study are encouraging and would promptly act as a supportive tool for forensic practitioners and general law enforcement, to the extent that it can provide information as a presumptive indicator of the sex of the person of interest. It may also be used as a supportive tool in disaster victim identification efforts. Hence, where it works, the state would save time and resources in narrowing down the right individuals from what can be very large lists. It is hoped that the proposed flowchart generated by this study is well-used in the field and become an indicator for further research.

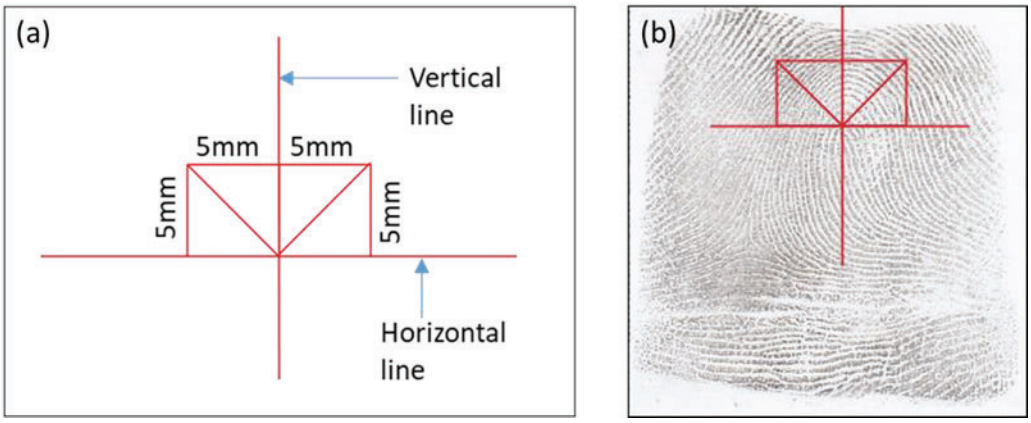

Figure 1 (a) The vector object and (b) Positioning of the vector object on a fingerprint.

Table 1 Descriptive statistics of fingerprint ridge density in the radial and ulnar areas in both hands combined for all 3 groups with t-value and p-value

Statistics	**Maldivian male**		**Maldivian female**		**Bangladeshi male**	
	Radial	**Ulnar**	**Radial**	**Ulnar**	**Radial**	**Ulnar**
Mean	14.21	12.79	15.31	15.05	13.65	13.50
Median	14.20	12.80	15.20	14.90	13.65	13.50
Maximum	20	20	22	23	19	20
Minimum	10	10	10	9	10	10
SD	1.32	1.14	1.57	1.49	1.36	1.25
t- value	19.276**		2.781**		2.172*	
p-value	0.000		0.006		0.032	

**Significant at p-value < 0.01; *Significant at p-value < 0.05

Table 2 Probability densities, likelihood ratios and favored odds derived from the right hand ulnar and radial area of Maldivian male (MM) and Bangladeshi male (BM).

	Right hand						
	Ridge density / 25 mm²	Probability		Likelihood ratio		Favored odds	
		MM	BM	MM/BM	BM/MM	MM	BM
Radial area	10	0.03	0.03	0.94	1.07	0.48	0.52
	11	0.06	0.07	0.78	1.29	0.44	0.56
	12	0.13	0.20	0.64	1.55	0.39	0.61
	13	0.16	0.23	0.69	1.44	0.41	0.59
	14	0.19	0.16	1.19	0.84	0.54	0.46
	15	0.21	0.14	1.55	0.64	0.61	0.39
	16	0.12	0.10	1.18	0.85	0.54	0.46
	17	0.07	0.04	1.55	0.65	0.61	0.39
	18	0.02	0.02	1.38	0.73	0.58	0.42
	19	0.01	0.00	1.50	0.67	0.60	0.40
	20	0.00	0.00	0.00	0.00	0.00	1.00
Ulnar area	10	0.02	0.03	0.75	1.33	0.43	0.57
	11	0.06	0.09	0.63	1.59	0.39	0.61
	12	0.12	0.15	0.75	1.33	0.43	0.57
	13	0.21	0.20	1.06	0.94	0.51	0.49
	14	0.19	0.22	0.87	1.15	0.47	0.53
	15	0.18	0.17	1.02	0.98	0.51	0.49
	16	0.13	0.08	1.61	0.62	0.62	0.38
	17	0.06	0.03	2.00	0.50	0.67	0.33
	18	0.03	0.02	1.56	0.64	0.61	0.39
	19	0.01	0.00	2.00	0.50	0.67	0.33
	20	0.00	0.00	1.00	1.00	0.50	0.50

Table 3 Probability densities, likelihood ratios and favored odds derived from the left hand ulnar and radial area of Maldivian male (MM) and Bangladeshi male (BM).

	Left hand						
	Ridge density / 25 mm²	Probability		Likelihood ratio		Favored odds	
		MM	BM	MM/BM	BM/MM	MM	BM
Radial area	10	0.02	0.05	0.42	2.36	0.30	0.70
	11	0.05	0.07	0.69	1.46	0.41	0.59
	12	0.10	0.18	0.57	1.77	0.36	0.64
	13	0.20	0.25	0.77	1.30	0.44	0.56
	14	0.21	0.19	1.11	0.90	0.53	0.47
	15	0.18	0.13	1.42	0.71	0.59	0.41
	16	0.13	0.08	1.60	0.63	0.62	0.38
	17	0.07	0.04	1.94	0.51	0.66	0.34
	18	0.04	0.00	10.50	0.10	0.91	0.09
	19	0.00	0.00	0.00	NA	0.00	0.00
	20	0.00	0.00	NA	NA	0.00	0.00
Ulnar area	10	0.02	0.06	0.27	3.75	0.21	0.79
	11	0.06	0.05	1.16	0.86	0.54	0.46
	12	0.12	0.14	0.82	1.22	0.45	0.55
	13	0.18	0.20	0.88	1.13	0.47	0.53
	14	0.25	0.22	1.15	0.87	0.53	0.47
	15	0.15	0.16	0.94	1.07	0.48	0.52
	16	0.12	0.10	1.20	0.84	0.54	0.46
	17	0.07	0.05	1.46	0.69	0.59	0.41
	18	0.03	0.01	2.67	0.38	0.73	0.27
	19	0.00	0.01	0.67	1.50	0.40	0.60
	20	0.00	0.00	NA	0.00	0.00	0.00

5. Conclusions and recommendations

This study aimed to determine differences in Maldivian and Bangladeshi men using fingerprint ridge density as a determinant for its potential forensic use. Additionally, ridge density differences between Maldivian males and females were also investigated for the same purpose. This was the

first study of its kind to be conducted on the Maldivian population and mainly agrees with previous work examining other world populations and sub-populations in that there is significant sex difference when ridge density is quantified. This study demonstrated that in the Maldivian population, females had higher fingerprint ridge density compared to males. This was observed in both radial and ulnar areas of the fingerprints examined in the dataset and the differences were found to statistically significant.

Further study on ridge density of individual fingers and thumbs in these population groups can be done to ascertain whether this gains discriminatory power for sex and population differences. From an anthropological perspective, sampling larger numbers in different regions of Maldives can contribute to the knowledge on Maldivian ancestry, which is largely linguistic, oral and written history, apart from more recent genetic studies.

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