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Evaluating the potential application of palmprint creases density for sex determination: an exploratory study

Roszaharah Yaacob[1], Helmi Hadi[1], Haidi Ibrahim[2], Yusmazura Zakaria[3] and Nik Fakhuruddin Nik Hassan[1*]

Abstract

Background: Identification of sex plays a vital role in forensic and medicolegal investigations. Although several studies were conducted in the past to assess sexual dimorphism in friction ridge skin characteristics, a similar study has not been attempted using creases characteristics. The present study was carried out to determine the sex differences based on creases density among the Malaysian population. A novel method was proposed by measuring creases density in 2 cm × 2 cm square at the hypothenar region on the right palmprints to evaluate its feasibility for sex discrimination purposes. A total of 150 subjects were investigated in this study.

Results: Results revealed that significant differences were observed in the creases density for males and females. Palmprint mean creases density of 3.46 creases/cm^2 and 5.73 creases/cm^2 were calculated in male and female subjects, respectively. Results indicated that females tended to have a significantly higher creases density than males in the selected region. Analysis using the independent sample *t*-test demonstrated that the creases density of males and females was significantly different ($p < 0.001$), with mean differences ranging between −2.90 and −1.65.

Conclusions: It is evident that palmprint creases density is a potential indicator for sex determination.

Keywords: Palmprint, Creases density, Sex determination

Background

Identification means the determination of the individuality of a person. It can be either complete (absolute) or incomplete (partial). Complete identification will provide a definitive fixation of a person's identity, while insufficient identification will reveal some facts of an individual like sex, age, and race (Kapoor and Badiye 2015). Palmprint is an image of a palm area of a hand that can be either in the form of a photograph of a hand or an impression left on a surface (Nibouche et al. 2012). Region for palmprint starts from the wrist to the root of the fingers, and it can provide a lot of information that can be used in personal identification. Since the palmar surface covers a large area compared to a fingerprint, a palmprint contains more information and many features that can easily be extracted for identification (Kong et al. 2009).

Personal identification based on palmprints in the context of forensic science is of paramount importance because 30% of latent prints recovered from crime scenes are from palms (Jain and Feng 2009). Oftentimes, the prints collected from crime scenes and weapons used by criminals belong to palms (Kanchan et al. 2013). Palmprint theoretically fulfils the foundation of identification which is permanent and unique. Palmprint's uniqueness originates during human foetal development of friction skin (David 1991), and it is permanent until death (Krishan et al. 2014).

In the palmprint recognition process, two unique features are used in analysing palmprint, namely friction

*Correspondence: nikf@usm.my
[1] Forensic Science Programme, School of Health Sciences, Universiti Sains Malaysia, Kota Bharu, Malaysia
Full list of author information is available at the end of the article

ridges and the palmar flexion creases. The discontinuities in the epidermal ridge patterns are called palmar flexion creases. Palmar creases appear before the formation of friction ridges during the embryonic skin development stage (Jain and Feng 2009), and both of them develop concurrently with the volar pads (Hays 2013). Palm creases and friction ridges share similarities as both are permanent until decomposition due to death and unique due to the growth, development, and regression of volar pads (David 1991). Thus, these factors qualify themselves as features in palmprint recognition.

Personal identification based on creases is very rare. There is no record of total crease extraction used for personal identification on palmprint (Chen et al. 2001). Due to their rarity, many examiners may not be aware of their existence, or the lack of published data likely limits the willingness of latent print examiners to proceed with the identification (Hays 2013). The possibility to use creases as a characteristic for palmprint identification exists because it lies within the same biological process that supports friction ridge skin identification. Palmar flexion creases can be used in personal identification in cases when the palmprint is lacking in ridge detail. Hence, the same methodology employed to identify friction ridge skin can be utilised to identify palmar flexion creases.

In the identification of palmprint based on friction ridge skin, the method used is by measuring the total ridge count (TRC) and friction ridge density. Ridge density is defined as the ridge count that corresponds to a defined area (Kapoor and Badiye 2015; Gutirrez-Redomero et al. 2011). Density is the first method that allows the assessment of all types of patterns on fingers and palms. These methods can also be applied to identify palmprints based on features of creases.

Currently, the palmprint recognition system is focussing more on sorting out prints based on populations without giving much attention to the impact of sex. The ever-increasing number of crimes in this country has made palmprints a crucial tool in the investigation process. If the sex of an individual is established with certainty, the burden of the crime investigator can be reduced by half (Nayak et al. 2010; Krishan et al. 2013). In such cases, identification of sex will help an investigating officer to narrow down the investigation. Numerous studies have attempted to develop sex estimation methods based on friction ridge density (Mundorff et al. 2014) and palmar tri-radii (Badiye et al. 2019; Jerković et al. 2021). To the best of our knowledge, the use of palmprint creases density for sex discrimination among Malaysians has never been explored (Roszaharah et al. 2016). The present study aims to study the variability of palmprint creases density in the Malaysian population and its significance in the determination of sex in forensic examinations.

Methods

A total of 150 subjects (75 males and 75 females) aged between 18 and 20 years were randomly chosen. Ethical approval for the study was obtained from the institutional ethics committee, and all subjects filled consent form individually. The palmprint images used in our research were acquired through a general scanner, which was a Canon E400 series. The images were scanned at 300 dpi × 300 dpi and saved in JPEG format. They were 24-bit-per-pixel colour images with a size of 2488 × 3484 pixels (i.e. around 8.6 Mpixel image). Examples of input image used in this experiment is depicted in Fig. 1a. There were also six markers or pegs in each image. These markers were used to help the subjects to align their hand during image acquisition.

A 2 cm × 2 cm square was drawn and cropped on the palmprint images by using Adobe Photoshop (Fig. 1b). The beginning of distal transverse creases was used as a starting point for drawing the square in the hypothenar region. The palmprints were manually analysed in the region of interest (ROI) (Krishan et al. 2014). Some alterations of the hue, brightness, and contrast were also made to increase the clarity of the creases Three pixels and more creases were drawn and traced by using Bamboo Pad, a wireless touchpad with a digital stylus (Wacom, China). In the online palmprint matching system, three pixels produced 100% genuine acceptance rate (GAR) (Jerković et al. 2021). Thus, in this study, we selected three pixel lines to draw creases to increase the identification accuracy. The creases were divided based on their directions: creases shift to the right, and creases shift to the left. Different colours for tracing were used to differentiate the directions of the creases in the ROI. Yellow colour was used on the creases that shift to the right, while pink colour was used to trace the creases that shift to the left. The example of traced creases in the ROI is illustrated in Fig. 1c. Any bifurcation palmar creases were counted individually as independent creases, i.e. a crease that bifurcates was counted as two. The total numbers of creases in the square were counted. This value represented the number of creases in 4 cm^2 areas and reflected the creases density value.

The main objective of this study was to evaluate whether sufficient sexual dimorphism exists in the palmprint creases density using the sex estimation method on an unknown palmprint. To examine intra and interobserver repeatability, the first analyst repeated measurements on 40 randomly selected samples, and the second analyst conducted measurements on the same samples. Intra- and interobserver repeatability was examined

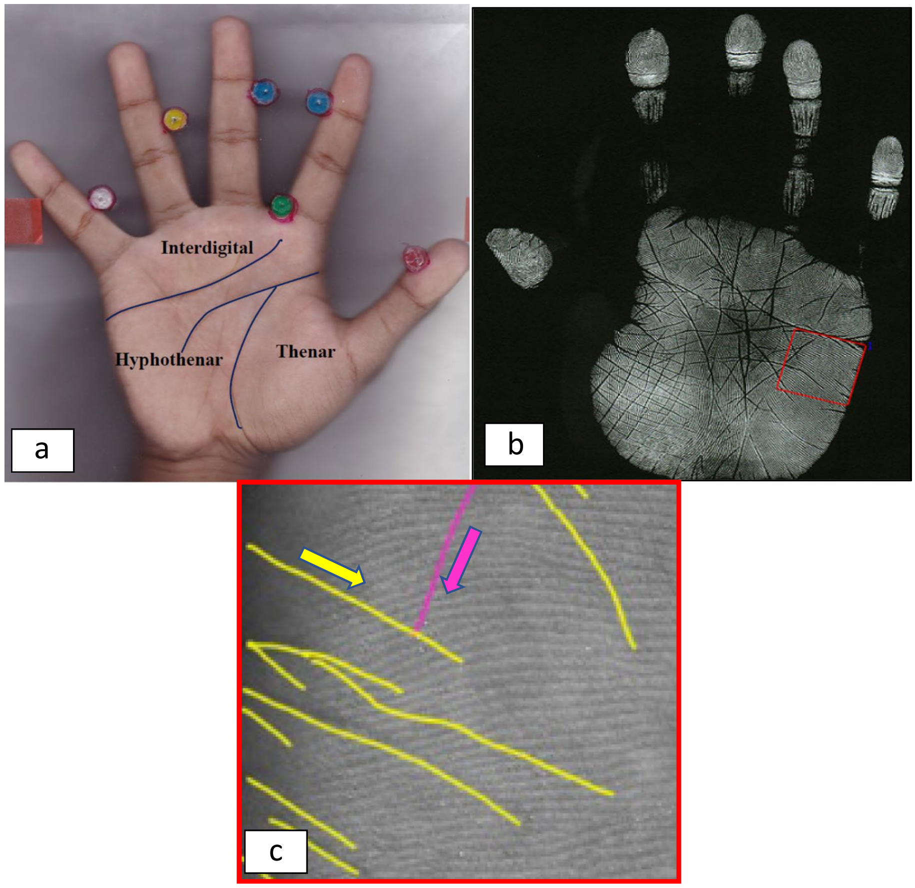

Fig. 1 **a** Position of right palm for palmprint sampling. **b** 2 cm × 2 cm square region of interest (ROI) at hypothenar was drawn, and the beginning of distal transverse creases was used as a starting point (marked as fix point 1). **c** 3 pixels and more creases were drawn based on direction; yellow colour was used to trace creases that shift to the right and pink colour for creases that shift to the left

using a paired samples *t*-test, technical error of measurement (TEM), and relative technical error of measurement (rTEM). The samples were statistically analysed by obtaining the total and group descriptive values using SPSS version 22 (IBM Corporation, USA), and a comparison between sexes was carried out to determine its significance.

Results

All measurements demonstrated a high degree of repeatability for both on the intra- and interobserver levels. Differences between the mean values of different observations were not statistically significant ($p > 0.05$), and the obtained rTEM values were lower than 2% for both intra- and inter-observer.

The descriptive statistics of palmprint creases for male and female subjects are tabulated in Tables 1 and 2, respectively. The creases shift to the right ranged from 1 to 34 creases for males with a mean of 9.77 and from 6 to 37 for females with a mean of 16.36. On the other hand,

Table 1 Descriptive statistics: creases shift to the right and the left in males and females

Type	Sex	Min	Max	Mean ± SD
Creases shift to the right	Male ($n = 75$)	1	34	9.77 ± 6.36
	Female ($n = 75$)	6	37	16.36 ± 5.99
Creases shift to the left	Male ($n = 75$)	0	13	4.05 ± 2.68
	Female ($n = 75$)	0	15	6.56 ± 3.12

Table 2 Descriptive statistics: total creases and creases density in males and females

	Sex	Min	Max	Mean ± SD
Total creases	Male ($n = 75$)	2	37	13.83 ± 7.71
	Female ($n = 75$)	11	46	22.92 ± 7.61
Creases density	Male ($n = 75$)	0.50	9.25	3.46 ± 1.94
	Female ($n = 75$)	2.75	11.50	5.73 ± 1.91

the creases shift to the left ranged from 0 to 13 creases for males with a mean of 4.05 and from 0 to 15 for females with a mean of 6.56. Higher numbers of creases shift to the right were observed for both sexes. The total creases at hypothenar ranged from 2 to 37 creases for males with a mean of 13.83 and from 11 to 46 for females with a mean of 22.92. The creases density ranged from 0.50 to 9.25 creases/cm^2 for males with a mean of 3.46 creases/cm^2 and from 2.75 to 11.50 creases/cm^2 for females with a mean of 5.73 creases/cm^2.

The independent sample *t*-test results to compare the creases density between males and females are depicted in Table 3. The differences in the creases density of males and females were statistically significant ($p < 0.001$), with a mean difference between −2.90 and −1.65. The difference between the mean creases density among males and females was −2.27 creases/cm^2. The frequency distribution of creases is shown in Figs. 2 and 3. Both males and females demonstrated normal distribution patterns regarding the pattern of distribution of creases shift to the right and to the left, total creases count, and creases density on the palm. However, the female palmprints showed significantly higher value counts for all characteristics.

Discussion

In forensics, an evidence needs to be able to narrow down suspects or victims in the identification process, including sex determination. With the increase of criminal cases and identity impersonation methods, previous ways of personal recognition are deemed insufficient (Fang 2007). Therefore, alternative methodologies, new identification metrics, or an addition to the existing identification strategies are crucial. Thus, new methods like personal recognition based on creases on palmprints will be beneficial to fingerprints experts and law enforcement communities (Cook et al. 2010). Palmprint is one of the popular biometric features used in the pattern recognition system (Rodríguez-Ruiz et al. 2019). Unfortunately, only a few studies have been carried out to utilise palmprints as an identification method in forensic science. Most of the past studies were conducted on fingerprints despite palmprints having many potentials for forensic individualisation. Features on palmprints are also stable as most of these features remain unchanged in an individual life span (Yaacob et al. 2019). Despite this lack of research, palmar flexion creases are considered a viable personal identification medium by some experts in this field. In fact, a previous study on ridge count in fingerprints suggested that palmar traits such as creases revealed extreme homogeneity compared to ridges (Karmakar et al. 2008). The results of our study showed that creases on palmprints could also be utilised to identify the sex of an individual.

The findings showed that higher counts for creases shift to the right, creases shift to left, total creases, and creases densities were calculated and compared between females and males. The different variations in males and females could be reflected during the prenatal embryonic development in a period called the palmar formation period (Karmakar et al. 2008; Stinson 1985). The factor that causes the difference in friction ridge density between fingerprints of males and females would also be applied to the palmprint feature as it develops in the same way during the pregnancy period (Wahdan and Khalifa 2017). The prenatal sex differences in environmental sensitivity can play a role in establishing sexual dimorphism in fingerprints because women are generally more resistant to environmental insults than men (Ahmed and Osman 2016). In addition to that, the fact that males have coarser epidermal surfaces than females could be one of the factors influencing lower crease density in males than females (Kralik and Novotny 2003).

Several other factors could also attribute to the sex difference. One of these factors would be the sexual dimorphism in body size and proportions (Wahdan and Khalifa 2017). Generally, males have a larger body size and proportions than females, causing variations in the male and female features, and relatively, males have a larger size of hand or palmar surface as compared to females (Kirchengast and Marosi 2009). Females are more canalised in their development than males and are less affected by environmental insults. Environmental effects that influence the development of features on the palm are dermal growth, the thickness of the foetal epidermis, the elevation of the embryonic pad, and the position of fingers (Hays 2013).

The significant mean difference in the creases density is important to prove dissimilarities between both sexes. The findings also demonstrate that creases density has a potential application in predicting the sex from unknown palmprints found at the crime scene as the hypothenar region is the area typically encountered in the palmprints. Since no other study has attempted using creases as a sex estimation method, a comparison of results can only be made with previous studies that have utilised the

Table 3 Independent sample *t*-test comparison of males and females creases density

Variable	Mean (SD)		Mean difference (95% *CI*)	t-stat (df)	*P*-value
	Male (*n* = 75)	Female (*n* = 75)			
Density	3.46 (1.94)	5.73 (1.91)	−2.27 (−2.90, −1.65)	−7.223 (148)	< 0.001

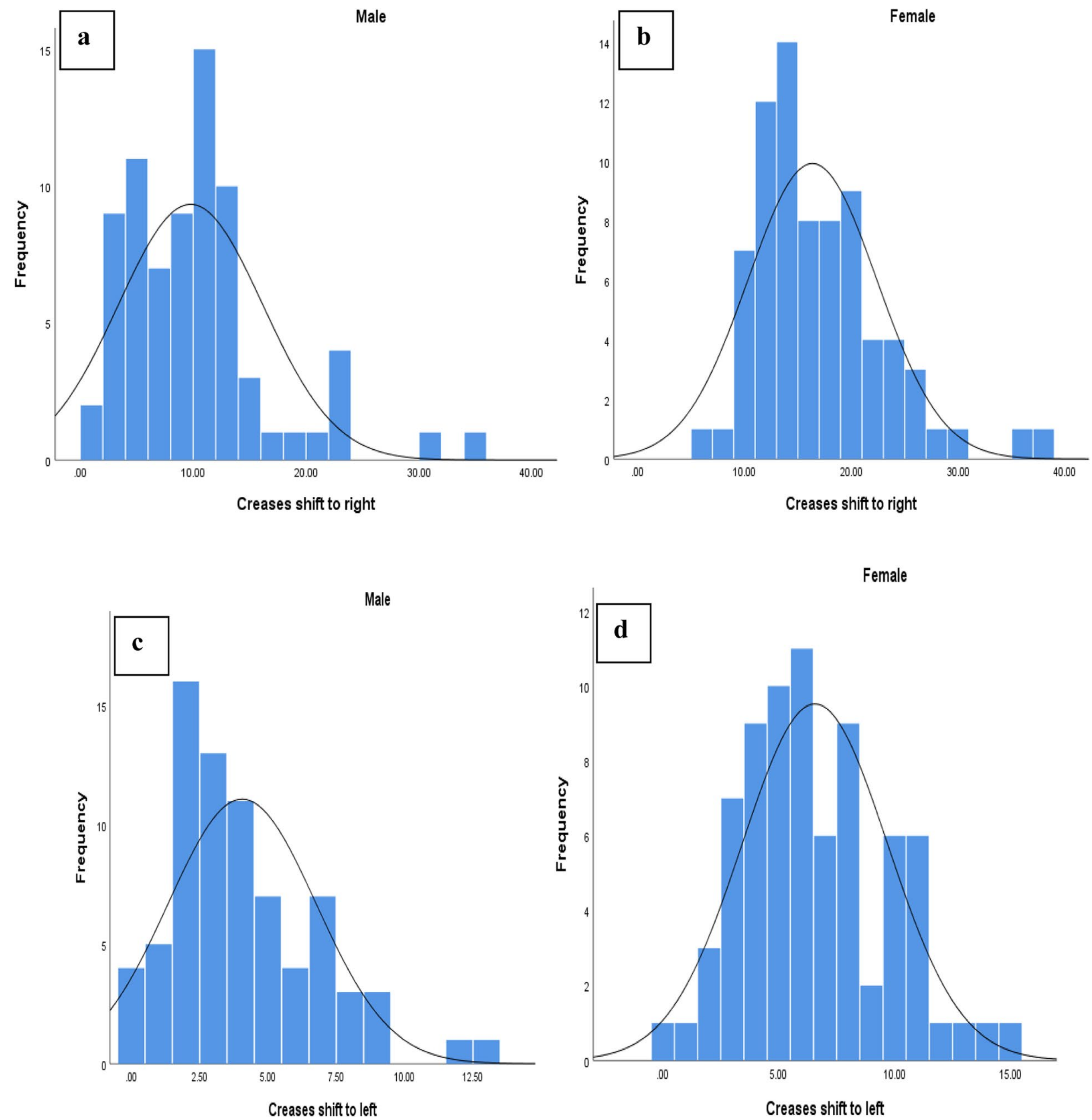

Fig. 2 Frequency distribution of mean creases shift to the right for **a** males and **b** females, and creases shift to the left for **c** males and **d** females

ridge density and palmar tri-radii methods. Past studies reported that females had higher ridge density than males in the area of the analysis in the palm (Kapoor and Badiye 2015; Krishan et al. 2014; Nayak et al. 2010; Gutiérrez et al. 2013; Dhall and Kapoor 2015). In addition to that, significant differences were also observed in the palmprint ridge density for sex detemination (Krishan et al. 2014). Female palmprints were observed to show significantly higher counts for all characteristics. These results were in agreement with a previous study that reported that the quantitative value of palmar features was lower in males, and heterogeneity was mostly marked in females (Rodríguez-Ruiz et al. 2019). The application of palmar tri-radii (delta) for sex determination was also reported in the previous studies. The distance between the deltas 'a', 'b', 'c', and 'd' to the axial tri-radius 't' was measured individually as well as combined using handheld illuminated microscope (Badiye

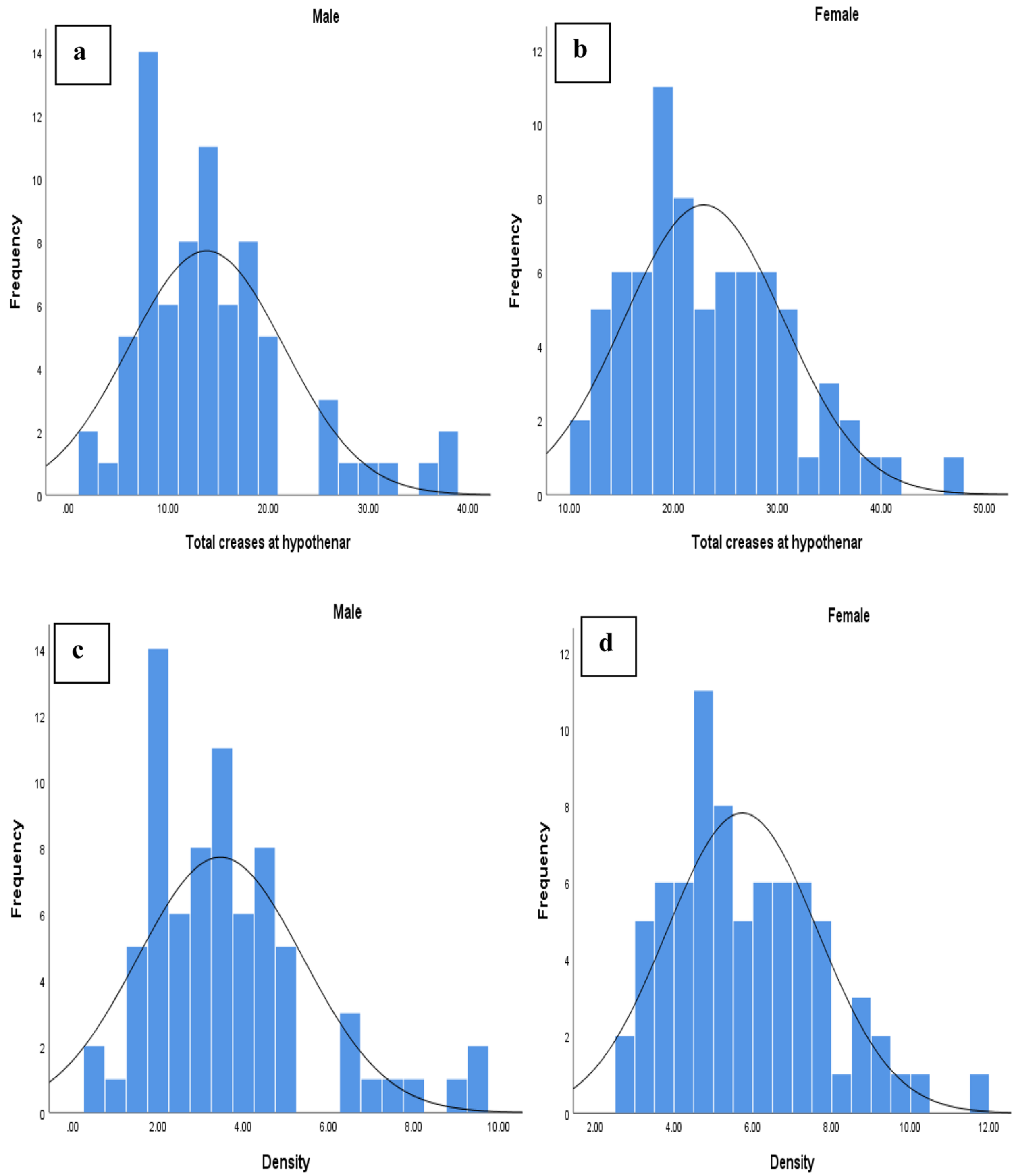

Fig. 3 Frequency distribution of mean total creases at hypothenar for **a** males and **b** females and creases density for **c** males and **d** females

et al. 2019). The combined distances of ≤ 30 cm and ≥ 32.5 cm have a higher probability of belonging to female and male donors, respectively. Another similar study has also demonstrated that measurements of the interdigital palmar area utilising the distances between digital triradii on the palm were statistically significant and could be used for estimating sex from palmprints in the Croatian population (Jerković et al. 2021).

Furthermore, it was demonstrated that 2 cm × 2 cm square ROI in this study could be utilised to calculate the crease density and be proposed in palmprint examination workflow. In this study, the same size of ROI was analysed for all palmprint samples regardless of hand size and sex. Hence, the same numbers of creases may be distributed in a larger palmar surface area, leading to lower crease density among males. In addition, the palmar characteristics have a relatively longer growth period as compared to fingers, and the prenatal environmental factors influence their developments (Karmakar et al. 2008). Therefore, characteristics in palm such as creases may have a uniqueness that can be used in the recognition process.

The findings of this study suggest that crease on palmprint can be used as an alternative to the traditional method, which usually uses minutiae point and friction ridge as identification features. In this case, the same method used to identify friction ridge skin can be used to identify palmar flexion creases. Palmprint contains eight times the number of minutiae points compared to fingerprints, and it has a large number of creases (Cook et al. 2010). Thus, extracting minutiae on palmprint is time-consuming compared to fingerprint since it has a larger area to analyse, and many creases need to be removed before they can be used for identification purposes. Creases on palmprints can also be used for identification if the palmprint evidence is in low resolution. The crease can be observed as it is a more prominent feature than the minutiae point, which can only be analysed in high-resolution prints (Chen et al. 2001). Although the formation path of the major and minor crease is genetically controlled, the secondary crease appears at random, and it is unique to the individual (Cook et al. 2010). Many examiners put effort into comparing the frequencies of various patterns such as palmar flexion creases in order to reveal the anthropologic characters of the different races of the populations (Park et al. 2010). Besides that, previous research have shown that palmar features have a high tendency to show the background of the populations as opposed to fingers (Karmakar et al. 2008).

Palm creases have the potential to complement with minutiae details in the identification of palmprint, and thus, these characteristics increase the evidential value of palmprint. Moreover, like friction ridge skin, the biological process makes palmar features permanent and unique (Jain and Feng 2009). In the examination of palmprint, creases commonly serve as supportive information for identifying or eliminating distorted latent palmprints. In addition to that, the experts usually use creases to determine the orientation of the palm as the size of creases is larger than the ridge pattern and easier to examine. Although the major creases are usually genetically dependent, most of the other creases are not formed based on genetic factors. Even identical twins that have similar genetic factors will have different palmprints. This nongenetic or environmental factor in pregnancy will form complex patterns or creases that are very useful in personal identification (Kong et al. 2009). Although identification of palmprint based on creases is not common, it is possible, and it plays an important role in palmprint verification (Huang et al. 2008). In summary, this study strongly encourage the use of creases density as identification means for sex determination, and due to the many benefits of creases characteristics, it can be explored further for forensic individualisation purposes.

Conclusions

This study is one of its kind since no research has attempted to compare the crease density in palmprints for sex identification in Malaysia. The findings confirmed that females had higher creases density than males in the Malaysian population. Thus, the mean creases density can be used as a sex determination method to reveal sex information from an unknown palmprint left at a crime scene. The palmprint mean creases density of 3.46 creases/cm^2 is more likely to be of male origin, and a mean of 5.73 creases/cm^2 is more likely to be of female origin in the Malaysian population. The findings presented in this study propose a new personal identification related to sex determination to complement the ridge density method. Further comparative studies on creases density of latent palmprints are warranted to establish and validate its potential to be utilised on developed/lifted latent print recovered from a crime scene. Similar study shall be also conducted and tested in other population samples.

Abbreviations

GAR: Genuine acceptance rate; ROI: Region of interest; rTEM: Relative technical error of measurement; TEM: Technical error of measurement.

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Authors' contributions

All authors contributed to the design of the study. Roszaharah performed the experiments. All authors analysed the data and discussed and wrote the manuscript. The author(s) read and approved the final manuscript.

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Availability of data and materials

Please contact the author for data requests.

Declarations

Ethics approval and consent to participate

Informed consent has been obtained from the participating individual. Ethical approval ref: USM/JEPeM/15090304.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Forensic Science Programme, School of Health Sciences, Universiti Sains Malaysia, Kota Bharu, Malaysia. [2]School of Electrical and Electronic Engineering, Universiti Sains Malaysia, Engineering Campus, Nibong Tebal, Pulau Pinang, Malaysia. [3]Biomedicine Programme, School of Health Sciences, Universiti Sains Malaysia, Kota Bharu, Malaysia.

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