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# The Study of Fingerprint Ridge Density in a Sample of Egyptian Population and its Application for Sex Identification

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**KEYWORDS**
Fingerprints
Ridge density
Identification
Sex
Egyptian population

## ABSTRACT

**Fingerprints have been used widely in human identification. The possibility of sex identification using fingerprints was based on a hypothesis that males have coarser ridges than females. The aim of the present work was to study the fingerprint ridge density as a method of sex identification in a sample of young Egyptian population. A cross sectional statistical study was carried out on 200 volunteers; 100 males and 100 females (age from 21 to 30 years). The epidermal ridges were counted in two distal (radial and ulnar) and one proximal region of each fingerprint. The radial and ulnar squares were placed directly on the radial and ulnar side of the central core region, while the proximal square was placed diagonally by placing one of its corners over the intersection of the joint line with the center line. The fingerprint mean ridge density of the three regions in all fingers, radial, ulnar and proximal regions were calculated and compared. Receiver–operating characteristic curves for predicting the probability of female gender were generated. Fingerprint ridge densities in the distal regions were significantly greater than in the proximal region in both sexes. Females showed significantly higher ridge density in the three regions for each and all fingers. The mean ridge density in all fingers at a cut off value >11.87 ridges/ 25mm$^2$ has a positive predictive value (PPV) of 90.09% for females, while the mean ridge density in radial region at a cut off value >12.2 ridges/ 25mm$^2$ has PPV of 86.96%. It is concluded that fingerprints are valuable in sex is identification in Egyptian population based on fingerprint ridge density. In addition, ridge density can be considered as a morphological feature for individual variation.**

## Introduction

Human identification is the act or process of recognizing one person as being a particular person (Clarke, 1994). There are numerous medico-legal reasons why it is important to establish the identity of a living individual or a dead body. The living may not be able to identify themselves for a variety of reasons; coma, amnesia, infancy or mental defects. Alternatively, an individual may simply chooses to conceal his true identity by providing false information. The identity of a corpse is of paramount importance in the investigation of any death and forms the first part of a coroner's inquisition (Shepherd, 2003).

The determination of sex is statistically the most important criterion of identification, as it immediately excludes approximately half the population whereas age, stature and race each provide points within a wide range of variables (Saukko and Knight, 2016).

Fingertips are covered with friction skin. This skin is covered with papillary ridges that assist in the ability to and hold onto objects. The patterns formed grasp in these ridges are very important since they are determined by the fourth month of gestation and remain fixed

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throughout life. Only severe mutilation or skin disease can cause them to change (Kelliher et al., 2005). The number of epidermal ridges is independent of age, and the ridges increase their width, without adding new ridges, to fit the hand and foot growth. Epidermal ridges and their arrangement (dermatoglyphic patterns) exhibit a number of properties that reflect the biology of an individual (Kralik and Novotny, 2003; Gutierrez-Redomero et al., 2011).

Fingerprints have been used widely in human identification. This is because no two individuals, even pairs of monozygotic twins, have the same prints (Taduran et al., 2016). The possibility of sex identification using fingerprints was based on a hypothesis that males have coarser ridges than females (Cummins et al., 1941). This hypothesis remained purely theoretical until Acree (1999) empirically tested it by counting ridges within a well-defined area, therefore considering both ridge and furrow breadth parameters. These values were compared by using statistical methods in order to determine if gender differences exist. Acree reported higher fingerprint ridge densities in females among Caucasian and African American population (Acree, 1999). Similar results in North Indian population were reported by Krishan et al. (2013). In more recent researches, similar observations were reported in Turkish population (Oktem et al., 2015) and in Sudanese population (Ahmed and Osman, 2016). So the aim of the present work was to study the fingerprint ridge density as a method of sex identification in a sample of young Egyptian population.

## Subjects and Methods

This study is a cross sectional statistical study carried out on 200 randomly selected Egyptian volunteers (100 males and 100 females), ranging in age from 21 to 30 years. This age was chosen to ensure fixed ridge width as ridge width varies according to age (Gutierrez-Redomero et al., 2011). They were Egyptian students, staff members and officials in different faculties in Tanta University. Subjects with any evidence of disease or injury of the fingertips that were likely to alter the fingerprint pattern were excluded. All subjects gave written informed consent to participate in the study.

Fingerprints were obtained from each subject by the simple ink-staining method described by Cummins and Midlo (1976). Porelon Fingerprint Pad (used for fingerprinting at the Egyptian Ministry of Interior), a sheet of $A_4$ white paper (divided into 10 blocks, one for the rolled print of each finger), a magnifying lens, and a transparent film were used.

First, the subjects were asked to wash and dry their hands to remove any dirt and grease. Then they were asked to press their right I, II, III, IV, V and the left I, II, III, IV, V fingers' distal phalanges (for thumb, index, middle, ring and little fingers respectively on the right and left sides) against the fingerprint pad and then transfer them to the paper. Regular pressure was applied and all 10 plain fingerprints were obtained using rolling technique to include radial and ulnar sides of each finger, and distal joint lines.

The fingerprint ridges were counted under the magnifying lens diagonally on a square measuring 5 mm × 5 mm according to the method described by Acree, (1999) and on the areas described by Gutierrez-Redomero et al. (2008). Three regions; radial, ulnar (distal regions) and proximal were used. To locate these counting regions, each fingerprint was divided into four sectors via two perpendicular lines crossing at the center of the type pattern and another horizontal line was placed parallel to the interphalangeal joint (joint line). In case of arches without a defined nucleus, the axes intersect at the center of the dactylogram on top of the arch. During determination of ridge

density in those regions, 5×5 mm squares (25 $mm^2$) drawn on the transparent film were used. For analysis of fingerprint ridge density in radial and ulnar regions squares were placed directly on the radial and ulnar side of the central core region respectively in such a way that the lowermost and innermost corner of the square was located on the central core of the fingerprint. For analysis of fingerprint ridge density in the proximal region a square was placed diagonally by placing one of its corners over the intersection of the joint line with the center line (Figure 1). The number of ridges was counted diagonally on these squares for both hands in each individual.

The collected data were organized and statistically analyzed using MedCalc Statistical Software version 15.8. Ridge counts for the three studied regions of all 10 fingers of each participant were obtained allowing an estimate of the median for each region (radial, ulnar and proximal) in each finger in both sexes. The mean of each region and the mean of the three regions of all fingers for all participants in both sexes were also estimated. For quantitative data, the Shapiro-Wilk test for normality was performed. For data that were not normally distributed median and interquartile range (expressed as $25^{th}$-$75^{th}$ percentiles) were calculated and Mann-Whitney was used for comparison between groups. For normally distributed data, values were expressed as mean ± standard deviation and independent samples t test was used for comparison. Repeated measures ANOVA was used to compare the mean ridge count in the three regions. Receiver–operating characteristic (ROC) curves for predicting the probability of female were generated from the data. Area under ROC curve, sensitivity, specificity, positive predictive values and positive likelihood ratios were calculated. The area under ROC curve (AUC) is graded as follows: 0.90-1= excellent; 0.80-0.90= good; 0.70-0.80 = fair and 0.60-0.70 = poor. Significance was adopted at $p < 0.05$ for interpretation of results of tests (Dawson and Trapp, 2001).

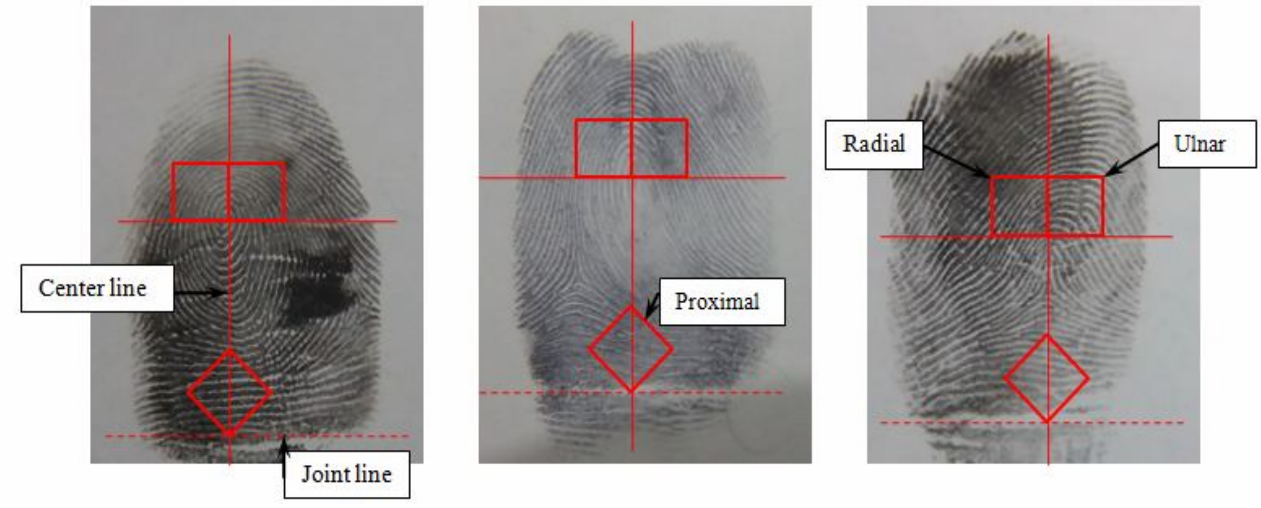


**Fig. (1):** Radial, ulnar and proximal regions (right hand) of a fingerprint where fingerprint ridge density was analyzed

## Results

The present study included 100 males with a median age of 25 years (ranging between 21 and 29 years) and 100 females with a median age of 27 years (ranging between 21 and 30 years). The descriptive analysis of fingerprint ridge densities in radial, ulnar (distal regions) and proximal regions of right and left hands in males and females are presented in tables 1 and 2.

The fingerprint ridge densities of the three selected regions were analyzed. The density in the ulnar region was greater than the redial region (the difference was statistically significant in males and non significant in females). The lowest ridge density encountered in the ulnar region was 8 and the highest was 17 with a mean of 11.79 ± 0.99 ridges/ 25 $mm^2$ in males and the lowest was 10 and the highest was 21 with a mean of 14.92 ± 1.5 ridges/25 $mm^2$ in females. Meanwhile the lowest ridge density encountered in the radial region was 8 and the highest was 18 with a mean of 11.53 ± 0.94 ridges/25 $mm^2$ in males and the lowest was 10 and the highest was 22 with a mean of 14.78 ± 1.38 ridges/25 $mm^2$ in females. A statistically significant lower ridge density was observed in the proximal region than that observed in the distal regions (7 to 14 with a mean of 10.15 ± 0.62 ridges/ 25 $mm^2$ in males and 8 to 16 with a mean of 11.83 ± 0.66 ridges/ 25 $mm^2$ in females).

The mean ridge density of the three regions in all fingers in females was significantly greater than that in males. In addition the mean ridge density in radial, ulnar and proximal regions in all fingers were also significantly greater than that in males (Table 3).

Table 4 and figure 2 show the results of analysis of ROC curve of fingerprint ridge count as a predictor of female gender. The optimal cut-off values of the four studied means for predicting female gender were identified. The mean ridge density of the three regions in all fingers has the best AUC followed by the mean ridge density in radial region, the mean ridge density in proximal region then the mean ridge density in ulnar region. There were significant statistical differences between the AUC values of the mean ridge density of the three regions in all fingers and the mean ridge density in radial and ulnar regions. In addition there was a significant statistical difference between the AUC values of the mean ridge density in radial region and the mean ridge density in ulnar region. The mean ridge density of the three regions in all fingers had 100% sensitivity (was able to predict 100% of cases that are females) and 89% specificity at a cutoff value >11.87 ridges/ 25 $mm^2$. The mean ridge density in radial region had a 100% sensitivity and 85% specificity at a cutoff value > 12.2, while the mean ridge density in proximal region had 88% sensitivity and 94% specificity at cut-off value > 13.2. The sensitivity and specificity of the mean ridge density in ulnar region were 88% and 91% respectively at a cutoff value > 11.

**Table (1):** Ridge count in radial, ulnar and proximal regions of right hand of the studied male and female participants (n: 200).

| | | Sex | | Mann Whitney test | |
|---|---|---|---|---|---|
| | | **Males (n=100)** | **Females (n=100)** | **Z** | **p** |
| Right I radial | Minimum- Maximum | 8- 15 | 10- 18 | - 10.162 | <0.001* |
| | Median (IQR) | 11 (10 - 12) | 14 (13 - 16) | | |
| Right I ulnar | Minimum- Maximum | 9 - 15 | 11 - 20 | - 9.445 | <0.001* |
| | Median (IQR) | 11 (11 - 12) | 14 (13 - 15) | | |
| Right I proximal | Minimum- Maximum | 8 - 14 | 9 - 15 | - 7.641 | <0.001* |
| | Median (IQR) | 10 (10 - 11) | 12 (11 - 13) | | |
| Right II radial | Minimum- Maximum | 9 - 14 | 11 - 19 | -10.851 | <0.001* |
| | Median (IQR) | 11 (10 - 12) | 14 (13 - 16) | | |
| Right II ulnar | Minimum- Maximum | 9 - 16 | 11 - 18 | -9.108 | <0.001* |
| | Median (IQR) | 12 (11 - 13) | 14 (13 - 15) | | |
| Right II proximal | Minimum- Maximum | 8 - 12 | 10 - 15 | -8.868 | <0.001* |
| | Median (IQR) | 10 (10 - 11) | 12 (11 - 13) | | |
| Right III radial | Minimum- Maximum | 9 - 17 | 11 - 20 | -9.845 | <0.001* |
| | Median (IQR) | 11 (10 - 12) | 15 (13 - 16) | | |
| Right III ulnar | Minimum- Maximum | 9 - 17 | 12 - 20 | -8.141 | <0.001* |
| | Median (IQR) | 12 (12 - 14) | 14 (14 - 16) | | |
| Right III proximal | Minimum- Maximum | 8 - 14 | 10 - 15 | -7.849 | <0.001* |
| | Median (IQR) | 10 (10 - 11) | 12 (11 - 13) | | |
| Right IV radial | Minimum- Maximum | 8 - 17 | 11 - 21 | -10.688 | <0.001* |
| | Median (IQR) | 11 (11 - 12) | 15 (14 - 17) | | |
| Right IV ulnar | Minimum- Maximum | 9 - 17 | 12 - 20 | -9.080 | <0.001* |
| | Median (IQR) | 12 (11 - 14) | 15 (14 - 17) | | |
| Right IV proximal | Minimum- Maximum | 8 - 13 | 9 - 15 | -7.829 | <0.001* |
| | Median (IQR) | 10 (10 - 11) | 12 (11 - 13) | | |
| Right V radial | Minimum- Maximum | 8 - 15 | 11 - 22 | -10.535 | <0.001* |
| | Median (IQR) | 11 (10 - 12) | 15 (14 - 17) | | |
| Right V ulnar | Minimum- Maximum | 9 - 16 | 11 - 19 | -8.378 | <0.001* |
| | Median (IQR) | 12 (11-13) | 15 (13-17) | | |
| Right V proximal | Minimum- Maximum | 8 - 14 | 10 - 16 | -6.318 | <0.001* |
| | Median (IQR) | 10 (10-11) | 11 (11-12) | | |

n: number, IQR: interquartile range, * significant at $p < 0.05$.

**Table (2):** Ridge count in radial, ulnar and proximal regions of left hand of the studied male and female participants (n: 200).

| | | Sex | | Mann Whitney test | |
|---|---|---|---|---|---|
| | | **Males (n=100)** | **Females (n=100)** | **Z** | **p** |
| Left I radial | Minimum- Maximum | 8 - 16 | 11 - 19 | -8.573 | <0.001* |
| | Median (IQR) | 12 (11-13) | 14 (13-16) | | |
| Left I ulnar | Minimum- Maximum | 8 - 14 | 10 - 20 | -9.239 | <0.001* |
| | Median (IQR) | 11 (10-12) | 14 (12-16) | | |
| Left I proximal | Minimum- Maximum | 7 - 13 | 9 - 15 | -8.771 | <0.001* |
| | Median (IQR) | 10 (9-11) | 12 (11-13) | | |
| Left II radial | Minimum- Maximum | 9 - 14 | 12 - 18 | -10.652 | <0.001* |
| | Median (IQR) | 12 (11-12) | 15 (13-16) | | |
| Left II ulnar | Minimum- Maximum | 9 - 15 | 10 - 20 | -10.641 | <0.001* |
| | Median (IQR) | 11 (11-12) | 15 (14-17) | | |
| Left II proximal | Minimum- Maximum | 8 - 13 | 9 - 15 | -8.985 | <0.001* |
| | Median (IQR) | 10 (9-11) | 12 (11-12) | | |
| Left III radial | Minimum- Maximum | 9 - 16 | 12 - 19 | -9.592 | <0.001* |
| | Median (IQR) | 13 (11-13) | 15 (14-17) | | |
| Left III ulnar | Minimum- Maximum | 9 - 16 | 12 - 20 | -10.138 | <0.001* |
| | Median (IQR) | 11 (11-13) | 15 (14-17) | | |
| Left III proximal | Minimum- Maximum | 8 - 12 | 8 - 14 | -8.040 | <0.001* |
| | Median (IQR) | 10 (9-11) | 12 (11-13) | | |
| Left IV radial | Minimum- Maximum | 8 - 18 | 11 - 20 | -9.641 | <0.001* |
| | Median (IQR) | 12 (11-13) | 16 (14-17) | | |
| Left IV ulnar | Minimum- Maximum | 8 - 16 | 10 - 20 | -9.668 | <0.001* |
| | Median (IQR) | 11 (11-13) | 16 (13-18) | | |
| Left IV proximal | Minimum- Maximum | 7 - 12 | 10 - 14 | -8.938 | <0.001* |
| | Median (IQR) | 10 (9-11) | 12 (11-12) | | |
| Left V radial | Minimum- Maximum | 9 - 15 | 12 - 19 | -9.763 | <0.001* |
| | Median (IQR) | 12 (11-13) | 14 (13-16) | | |
| Left V ulnar | Minimum- Maximum | 9 - 15 | 11 - 21 | -10.585 | <0.001* |
| | Median (IQR) | 12 (11-12) | 15 (14-16) | | |
| Left V proximal | Minimum- Maximum | 7 - 12 | 8 - 14 | -8.985 | <0.001* |
| | Median (IQR) | 10 (9-10) | 11 (11-12) | | |

n: number, IQR: interquartile range, * significant at $p < 0.05$.

**Table (3):** Mean ridge densities in male and female participants (n: 200).

| | | Sex | | | | Independent Samples T Test | |
|---|---|---|---|---|---|---|---|
| | | Males (n=100) | | Females (n = 100) | | | |
| | | Mean | SD | Mean | SD | t | p |
| **Mean ridge density of the three regions in all fingers** | | 11.16 | ٠.72 | 13.84 | 1.01 | -21.655 | <0.001* |
| **Mean ridge density in radial region** | | 11.53 | ٠.94 | 14.78 | 1.38 | -19.496 | <0.001* |
| **Mean ridge density in ulnar region** | | 11.79 | ٠.99 | 14.92 | 1.50 | -17.452 | <0.001* |
| **Mean ridge density in proximal region** | | 10.15 | ٠.62 | 11.83 | ٠.66 | -18.575 | <0.001* |
| **Repeated measures ANOVA** | **F** | 222.160 | | 401.520 | | | |
| | **p** | <0.001* | | <0.001* | | | |
| | **Post Hoc test** | P1(radial vs ulnar)<0.001*<br>P2 (radial vs proximal)<0.001*<br>P3 (ulnar vs proximal)<0.001* | | P1(radial vs ulnar)= 0.293<br>P2 (radial vs proximal)<0.001*<br>P3 (ulnar vs proximal)<0.001* | | | |

n: number, SD: standard deviation, * significant at $p < 0.05$.

**Table (4):** Comparison of different methods of ridge count in predicting female gender

| | | Mean ridge density of the three regions in all fingers | Mean ridge density in radial region | Mean ridge density in ulnar region | Mean ridge density in proximal region |
|---|---|---|---|---|---|
| **Cutoff value** | | >11.87 | >12.2 | >13.2 | >11 |
| **Sensitivity (%)** | | 100% | 100% | 88% | 88% |
| **Specificity (%)** | | 89% | 85% | 91% | 94% |
| **AUC** | | 0.988 | 0.978 | 0.960 | 0.971 |
| **P (Area=0.5)** | | <0.001* | <0.001* | <0.001* | <0.001* |
| **PPV** | | 90.09% | 86.96% | 90.72% | 93.62% |
| **+LK ratio** | | 9.09 | 6.67 | 9.78 | 14.67 |
| **Pair wise comparison of ROC curves** | **z statistic** | Mean ridges vs mean radial = 2.406<br>Mean ridges vs mean ulnar = 3.323<br>Mean ridges vs mean proximal = 1.944<br>Mean radial vs mean ulnar = 2.282<br>Mean radial vs mean proximal = 0.677<br>Mean ulnar vs mean proximal = 0.792 | | | |
| | **p value** | Mean ridges vs mean radial = 0.0161*<br>Mean ridges vs mean ulnar <0.001*<br>Mean ridges vs mean proximal = 0.052<br>Mean radial vs mean ulnar = 0.023*<br>Mean radial vs mean proximal = 0.498<br>Mean ulnar vs mean proximal = 0.428 | | | |

AUC: area under the curve, PPV: positive predictive value; +LK: positive likelihood; ROC: receiver operating characteristic, * significant at $p < 0.05$.

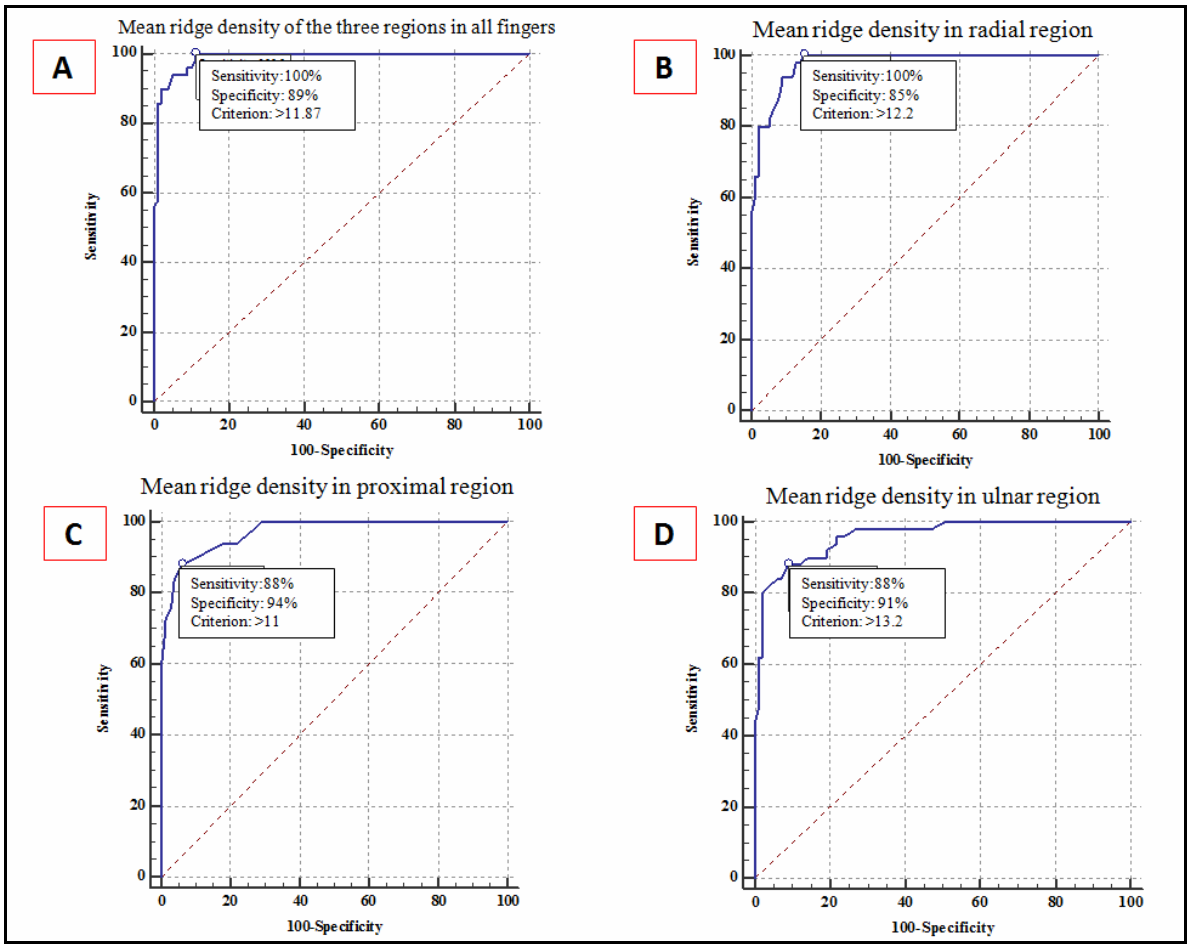


**Fig. (2):** Receiver–operating characteristic (ROC) curve analysis of [A] mean ridge density of the three regions in all fingers [B] mean ridge density in radial region [C] mean ridge density in proximal region and [D] mean ridge density in ulnar region as predictors of female gender

## Discussion

Fingerprints are an important part of human identification used in civilian cases for confirmation of the identity and in medico-legal cases, e.g., latent prints at a crime scene or dismembered fingers or hands (Nandy, 2001; Eshak et al., 2013). In spite of the new era of forensic genetics, fingerprints have several features that can play a crucial role in personal identification. For example, they are unique to each individual and are relatively stable. Furthermore they can easily be classified and easily be attained for comparison (Mundorff et al., 2014).

The present study recruited 200 participants of similar age group (ranging between 21and 30 years) who have completed their growth as the age was found to affect ridge breadth (Gutierrez-Redomero et al., 2011).

Variability in the fingerprint ridge densities on the three regions was observed in the current study, with lower ridge density in the proximal region compared to that in the distal regions. Previous studies done by Gutierrez-Redomero et al. (2013 a) in Argentinean population and by Krishan et al. (2013) in North Indian population have shown this topological distal-proximal gradient in densities, with ridge breadths being finest on fingertips and getting coarser in the

proximal areas in both sex. This difference could be attributed to either finer ridges, narrower valleys, or a combination of both in the distal areas.

Furthermore, the present study showed a higher ridge density in the ulnar than in the radial regions of the distal area. This may be because both sides of the finger are affected by differential developmental instructions and, therefore, the radial and ulnar areas were suggested to be considered as separate variables (Ahmed and Osman, 2016). This is in accordance with finding reported by Gutierrez-Redomero et al. (2013 b) in Sub-Saharan population and by Ahmed and Osman (2016) in Sudanese population. On the other hand, this finding disagreed with finding reported by Gutierrez-Redomero et al. (2011) in Mataco-Mataguayo population (South American population) and Oktem et al. (2015) in Turkish population who reported higher ridge densities in radial than ulnar region.

In the present study the mean ridge density of the three regions in all fingers, the mean ridge density in radial, ulnar and proximal regions in all fingers in females were significantly greater than that in males. These results are in agreement with many previous studies (Krishan et al., 2013; Gutierrez-Redomero et al., 2013 a; Oktem et al., 2015; Ahmed and Osman, 2016; Rivalderia et al., 2016). On the other hand, Gutierrez-Redomero et al. (2008) and Gutierrez-Redomero et al. (2011) found a significant difference in the mean ridge density in radial and ulnar regions and a non significant difference in the mean ridge density in the proximal region between males and females.

The lower ridge density in males than females could be attributed to the fact that males have coarser epidermal ridges than females and the difference is approximately 10% (Kralik and Novotny, 2003). In addition to this reason which is frequently mentioned in the literature, Krishan et al. (2010) proposed several factors that could contribute to this sex difference. One of these factors would be the sexual dimorphism in body size and proportions (males have larger body size and proportions than females) thus, the same numbers of ridges are accommodated in a larger surface area and this lead to lower fingerprint ridge density among males. Another factor could be related to sex chromosomes as it was proposed that the genes coding the dermal ridges are located on the X chromosome. If this is the case, it is logic to find females having more ridges compared to males. Finally, they have also suggested that the degree of ridge breadth might be correlated to the hand use. If males are assumed to use hands more intensely, an increase in the muscular development could be expected, which in turn could produce skin broadening of the ridges and a decrease of male ridge density (Krishan et al., 2010).

From the study of ROC curves of mean ridge densities, the mean ridge density of the three regions in all fingers had the best discriminatory power for identification of female gender as evidenced by its highest AUC followed by the mean ridge density in radial region, proximal region then ulnar region. A mean ridge density of the three regions in all fingers > 11.87 ridges/ 25mm$^2$ can predict female gender in a percentage of 90.09% (the gender is female 9.1 times more probable than male). A mean ridge density in radial region > 12.2 ridges/ 25mm$^2$ can predict females in a percentage of 86.96% (the gender is female 6.7 times more probable than male). A mean ridge density in proximal region >11 ridges/ 25mm$^2$ can predict females in a percentage of 93.62% (the gender is female 14.7 times more probable than male). A mean ridge density in ulnar region>13.2 ridges/ 25mm$^2$ can predict females in a percentage of 90.72% (the gender is female 9.8 times more probable than male).

These results were in partial agreement with results obtained by Ahmed and Osman

(2016) who found that the threshold for sexual discrimination using radial and ulnar fingerprint ridge density is a ridge count of 13 ridges/25 $mm^2$. Fingerprints showing up to 13 ridges/25 $mm^2$ in radial and ulnar areas have a high likelihood of belonging to men, whereas, the existence of 14 ridges/ 25 $mm^2$ increases the likelihood of the fingerprint belonging to a women. Hence, a count of 11 ridges/ 25 $mm^2$ in a radial area translates to 94% probability of the subject being male, while a count of 12 ridges/25 $mm^2$ in the ulnar indicates 75% probability of the fingerprint belonging to a male subject. The likelihood that the fingerprint belongs to a male individual becomes greater if the ridge count in the proximal area is 9 ridges/ 25 $mm^2$.

On the other hand, the cutoff values obtained in the present study were lower than the threshold for sex discrimination observed in other studies. Gutierrez-Redomero et al. (2008) suggested that a ridge count of 16 ridges or less per 25 $mm^2$ in radial region is more likely to correspond to a man's fingerprint, while a ridge count of 17 ridges or more per 25 $mm^2$ is more likely to correspond to that of a woman. In the ulnar area, a count of 14 ridges or less per 25 $mm^2$ is most likely to be of male origin, and a count of 17 ridges or more per 25 $mm^2$ is most likely to be of female origin. They stated that this could be interpreted as a threshold of gender differentiation. Oktem et al. (2015) found that a radial or ulnar ridge count $\geq$15/ 25$mm^2$ or a proximal ridge count >13/25$mm^2$ is more likely to be seen in a woman. In addition Taduran et al. (2016) stated that a radial ridge count of 13 ridges/25 $mm^2$ is more likely to be of male and a count of 16 ridges/25 $mm^2$ is more likely to be of female. An ulnar ridge count of 12 ridges/25 $mm^2$ is more likely to be of male and 14 ridges/25 $mm^2$ is more likely to be of female. They reported that the proximal area exhibited varying results and so they suggested that when this feature is used identification will be unreliable. The difference in threshold of ridge density for sex discrimination between these studies and the present study may be attributed to differences in populations studied (Spanish Caucasian, Turkish, Filipinos and Egyptian populations).

Although the mean ridge density of the three regions in all fingers had the best discriminatory power for identification of female gender, it was a difficult and time consuming process to count the ridges in the three regions together to calculate it. The mean ridge density in the radial region had the second best discriminatory power and counting the ridges in one region only is easy and more time saving.

## Conclusion

It is concluded that females have significantly greater fingerprint ridge densities than males over the three regions in each and all fingers. Hence, based on fingerprint ridge density fingerprints are valuable in sex identification in Egyptian population. In addition, ridge density can be considered as a morphological feature for individual variation in forensic anthropology.

## Recommendations

This study recommends the use of fingerprints in identification of sex based on the fingerprint ridge density. Calculating the ridge density in the radial region is recommended as it has a high discriminatory power and it is easy and time saving. Further studies to compare the fingerprint ridge density in larger number and different localities of Egyptian population are recommended.

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# دراسة كثافة الخطوط الحلمية في بصمات الأصابع في عينة من الشعب المصري و استخدامها في الاستعراف على الجنس

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تستخدم بصمات الأصابع في تحديد الهويه للبشر على نطاق واسع، و قد استندت إمكانية الاستعراف على الجنس باستخدام بصمات الأصابع على فرضية أن الذكور لديهم خطوط حلمية أكثر سماكه من الاناث. و قد كان الهدف من هذا العمل دراسة كثافة الخطوط الحلمية في بصمات الاصابع كوسيلة للاستعراف على الجنس في عينة من شباب الشعب المصري. هذه دراسة احصائية مقطعية على ٢٠٠ متطوع: ١٠٠ ذكور و ١٠٠ اناث (العمر من ٢١ إلى ٣٠ عام)، تم عد الخطوط الحلمية للبشرة في منطقتين بعيدتين (المنطقتين الوحشية و الانسية) ومنطقة واحدة قريبة في كل بصمه من بصمات الأصابع، وقد وضع كل من المربعين الوحشي و الانسي مباشرة على الجانبين الوحشي و الانسي من الخط الأساسي المركزي، في حين وضع المربع القريب بطريقه قطريه من خلال وضع احد أركانه على تقاطع خط المفصل مع الخط المركزي. تم حساب متوسط كثافة الخطوط الحلمية في كل الاصابع و في المنطقة الوحشية و الانسية و القريبه و مقارنتهم، و قد تم انشاء منحنيات استقبال العوامل المميزة (ROC) للتنبؤ باحتمالية الجنس الأنثوي، و قد كانت كثافة الخطوط الحلمية للبصمات في المناطق البعيدة أكبر بكثير من كثافتها في المنطقة القريبة في كلا الجنسين. و لقد أظهرت الإناث كثافة خطوط حلمية أعلى بكثير من الذكور في المناطق الثلاث لكل اصبع وجميع الأصابع، و قد كان لمتوسط كثافة الخطوط الحلمية لجميع الأصابع عند قيمة > ١١,٨٧ خط/ ٢٥ ملم$^{٢}$ قيمة تنبؤيه موجبه بنسبة ٩٠,٠٩٪ للجنس الأنثوي في حين كان لمتوسط كثافة الخطوط الحلمية في المنطقة الوحشية عند قيمة > ١٢,٢ خط/ ٢٥ ملم$^{٢}$ قيمة تنبؤيه موجبه بنسبة ٨٦,٩٦٪. وقد خلص إلى أن بصمات الاصابع ذات أهمية في الاستعراف على الجنس في الشعب المصري اعتمادا على كثافة الخطوط الحلميه. كما يمكن اعتبار كثافة الخطوط الحلمية كسمة مورفولوجية للفروق الفردية