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Original article

Study on Sex Differences in Fingerprint Ridge Density of Patent Thumbprints by Ink Staining Method in Young Adult Indian Tamil Population

دراسة عن الاختلافات بين الجنسين من الشباب البالغين من سكان الهند التاميل في كثافة نتوءات بصمات الأصابع الظاهرة من بصمات أصابع الإبهام بواسطة صبغها بالحبر.

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Abstract

The present study was conducted at the Forensic Medicine Department, Velammal Medical College Hospital & Research Institute, Tamil Nadu, India, with an objective to assess sex differences in thumbprint ridge density from patent thumbprints by ink staining method.

One hundred and thirty three Tamil speaking medical students, 19-21 years of age, participated in the study after obtaining their informed consent. Sample size was calculated using Sample Size Calculator presented as a public service of Creative Research Systems: Survey software, 'The Survey System'.

In the present study, loop pattern was found in 56% of thumbprints, whorl pattern in 32.7%, arch in 8.7% and composite pattern was found in 2.6% of thumbprints. Thumbprint ridge density ranged from 8-12 ridges/25 mm^2 in males and 10-14 ridges/25 mm^2 in females. Difference in ridge density of left and right thumbprints was not significant (p-value 0.8754). Difference in ridge density of fingerprint patterns was also not significant at $p < 0.05$.

The present study results will be beneficial for law enforcement authorities in identifying gender from thumbprints. Sex difference in thumbprint ridge density was significant at $p < 0.05$ and it was inferred that ridge density of ≤10 ridges/25 mm^2 is male and ≥11 is female.

Keywords: *Forensic Sciences, Forensic Medicine, Sex Difference, Thumbprint Ridge Density, Ink-Staining Method, Indian Tamil population.*

المستخلص

أجريت هذه الدراسة في قسم الطب الشرعي في كلية الطب ومعهد البحوث في مستشفى فيلامال Velammal. بهدف تقييم الفروق بين الجنسين في كثافة نتوءات البصمة لبصمات الإبهام بواسطة صبغها بالحبر.

شملت الدراسة 133 من طلاب الطب الناطقين باللغة التاميلية، والذين تتراوح أعمارهم ما بين 19-21 سنة. وتم حساب حجم العينة باستخدام "حاسبة حجم العينات" والتي قدمت كخدمة مجتمع من نظم البحوث الإبداعية: بواسطة برنامج المسح، "نظام المسح".

في الدراسة الحالية، تم العثور على نمط حلقي في 56٪ من بصمات الأصابع، ونمط وورلد (دوامة) في 32.7٪، ونمط التقوس في 8.7٪ والنمط المركب في 2.6٪ من بصمات الأصابع. تراوحت كثافة النتوءات من 8-12 نتوء / 25 ملليمتر مربع في الذكور و10-14 نتوء / 25 ملليمتر مربع في الإناث. الفرق في كثافة النتوءات بين بصمات الأصابع اليسرى واليمنى لم يكن كبيرا (كانت القيمة الاحتمالية، $p = 0.8754$). وكان الفروقات في كثافة النتوءات بين أنماط بصمات الأصابع أيضا ليست ذات دلالة احصائية عند مستوى القيمة الاحتمالية $p < 0.05$.

إن نتائج الدراسة الحالية مفيدة لسلطات إنفاذ القانون في تحديد نوع الجنس من بصمات الأصابع. كان الفرق بين الجنسين في كثافة نتوءات البصمة ذات دلالة احصائية عند مستوى دلالة $p < 0.05$ وقد استنتج الدراسة أن كثافة النتوءات أقل من أو يساوي ≥10 نتوء لكل 25 ملليمتر مربع في الذكور وأكثر من أو يساوي ≤11 نتوء في الإناث.

الكلمات المفتاحية: علوم الأدلة الجنائية، الطب الشرعي، الفرق بين الجنسين، كثافة نتوءات البصمة، طريقة الصبغ بالحبر، سكان الهند التاميل.

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1. Introduction

The study of dermatoglyphics (which deals with ridges and their pattern on the skin) can either be qualitative or quantitative. Qualitative dermatoglyphics focuses on fingerprint patterns, while ridge count and finger ridge density (RD) are quantitative elements in fingerprint study [1, 2]. Fingerprints are composed of ridges and furrows, and their formation is governed by genes and the environment (amniotic fluid) of the embryo during the first month of development [3, 4]. However, ridge number has been proven to be genetically inherited, with as much as 90–95% contribution by the genes. Thus, if populations are genetically distinct, RD is likely to differ between them [5, 6]. Fingerprints can be matched with known records to establish identity. But in the absence of a match, reliable data is required for sex identification from a fingerprint. The present study is a step towards identifying sex from thumbprint ridge density (TRD). Fingerprint ridge density, as defined by Acree, is 'ridge count in 5 x 5 mm^2 (25 mm^2) in a fingerprint'; and its applicability in gender determination is based on the fact that females tend to have finer ridge details compared to men and, therefore, have higher ridge density [7].

The present study was carried out at the Forensic Medicine department, Velammal Medical College Hospital & Research Institute (VMCHRI), Tamil Nadu, India,with an objective to assess sex differences in TRD from patent thumbprints by ink-staining method.

2. Materials and Methods

The present cross-sectional study was carried out from August to October 2017 at the Forensic Medicine department, Velammal Medical College Hospital & Research Institute, Madurai, Tamil Nadu. The study was approved (VMCIEC/44/2017) by the Institutional Ethics Committee (IEC) and was ethically conducted in accordance with the Declaration of Helsinki. Written informed consent was taken from all participants before data collection. Medical students of the institute participated in the study. Consenting Tamil speaking students, 19-21 years of age, were included (Inclusion Criteria). Students who were Non-Tamil speaking, with physical deformity (congenital / acquired) or previous trauma to the thumb were excluded from the study (Exclusion Criteria). The sample size was 133 (53 males and 80 females) of a total population of 142 students (confidence level at 95% and confidence interval of 2). Sample size was calculated using Sample Size Calculator presented as a public service of Creative Research Systems: Survey software, 'The Survey System'.

The ink-staining method was used for identifying thumbprints. Blue ink, an inking pad, a magnifier, and a predefined proforma (for data collection) were used. Plain thumbprints were obtained on to a predefined proforma by ink-staining method. The TRD was determined under a magnifier in three regions (radial, ulnar, & inferior regions of left & right thumb) by Acree's method [7]. Ridge density was determined as ridge count in 5mm x 5mm dimension squares (25mm^2) in these 3 regions. The ridges were counted along the diagonal line of the square. Dots were not counted, while forks and lakes were counted as two ridges. In this way, TRD was determined as 'ridge count/ 25 mm^2'. The squares (quadrants) were predefined in the proforma, as described by Oktem et al. in a manner so as to capture the radial, ulnar and inferior regions of the left and right thumbprints [8]. Radial and ulnar quadrants were positioned by placing their medial-inferior corners onto the center of the upper half of the thumbprint, and inferior quadrant was positioned in the lower half of the thumbprint

by placing one of its corners over the intersection of the first joint line with the center line. Figure-1 shows the position of the radial, ulnar & inferior quadrants on a thumbprint in the present study.

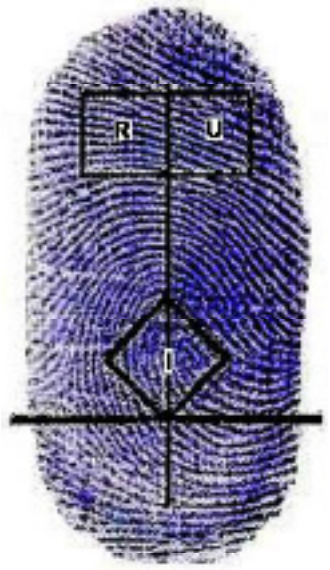

Figure 1- *Radial (R), Ulnar (U) and Inferior (I) quadrants on thumbprint.*

Ridge density (RD) in each of these quadrants was named as "left inferior quadrant ridge density (LIQRD), left radial quadrant ridge density (LRQRD), and left ulnar quadrant ridge density (LUQRD) for left thumbprints (LT133)". For right thumbprints (RT133), they were named as "right inferior quadrant ridge density (RIQRD), right radial quadrant ridge density (RRQRD), and right ulnar quadrant ridge density (RUQRD)". Observed values of ridge densities in LT133 and RT133, quadrant wise, namely LIQRD, LRQRD, LUQRD, RIQRD, RRQRD, and RUQRD were recorded for male (n = 53) and female (n = 80) participants. Fingerprint patterns were identified, using the Galton system, as loop, whorl, arch and composite pattern.

Unpaired t-test and Mann-Whitney U test were used to analyse data. The Mean (M), Standard Deviation (SD), Standard Error of Mean (SEM) and 95% Confidence Interval (95% CI) of the difference in mean of male and female ridge density (RD) were estimated by application of Unpaired t-test. Intermediate values in calculation were t value and standard error of difference (SED). 'U value' and 'Z score' were estimated using 'Mann-Whitney U test'. Statistical significance was known at $p < 0.05$.

3. Results

Of a total 266 thumbprints (LT133 + RT133), loop pattern was found in 56% (149) of thumbprints, whorl pattern in 32.7% (87), arch in 8.7% (23) and composite pattern was found in 2.6% (7) of thumbprints (Table-1 and Figure-2).

Table 1- *Gender wise distribution of fingerprint patterns.*

Fingerprint Patterns	Male (%)	*Female (%)*
Loop	55.70	56.30
Whorl	34	31.90
Arch	6.60	10
Composite	3.80	1.90

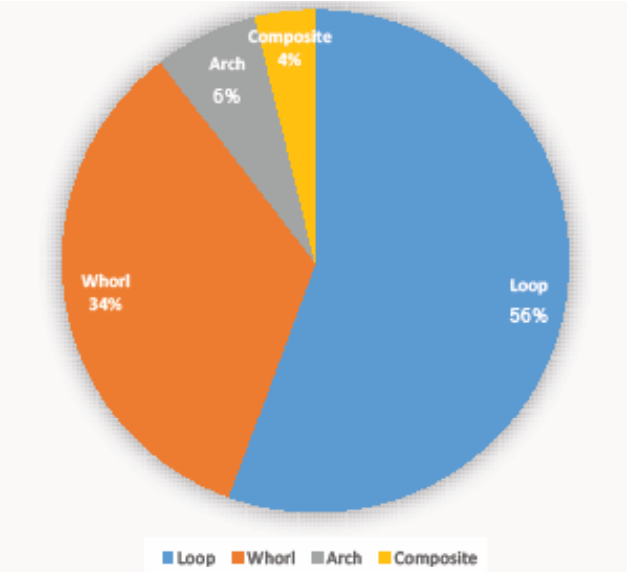

Figure 2- *Fingerprint pattern distribution in the present study.*

3.1 Statistical Findings on Ridge Density (Quadrant wise) in Male and Female Participants

The results were significant at $p < 0.05$, which meant that gender can be identified based on thumbprint ridge density of a known quadrant (Table-2). Table- 3 indicates statistical findings on ridge density of male and female participants in all quadrants. The results were significant at $p < 0.05$, which meant that gender can be identified based on thumbprint ridge density of an unknown quadrant, too.

Ridge density (RD) ranged from 8-12 ridges/25 mm^2 in males and 10-14 ridges/25 mm^2 in female participants. Considering mean and standard deviation, it was inferred that RD of ≤10 ridges/25 mm^2 is likely to be a male, and ≥11 ridges/25 mm^2 is female. Between left and right thumbprints of all participants, RD did not differ significantly (p-value 0.8754) with unpaired t-test, which meant that for a given individual, RD of left thumb can be considered similar to that of the right thumb. In the present study, loops and whorls had the major share amongst fingerprint patterns. Unpaired t-test was applied on these patterns to find if there was significant difference in their RD. However, the result was not significant at $p < 0.05$, indicating that fingerprint patterns do not play a significant role in thumbprint ridge density. Table- 4 shows the distribution of RD throughout the quadrants according to sex.

The likelihood ratio (LR) was calculated using ridge

Table 2- *Statistical findings on ridge density (ridges/25mm^2) (quadrant wise).*

Quadrant	Sex[n]	Mean	S.D.	SEM	CI.95	t-value	SED	U-value	Z-Score	*p*-value
LIQRD	**[M53]**	10.09	0.71	0.1	1.9-2.4	16.14	0.13	132	9.14	<0.0001
	[F80]	12.21	0.76	0.08						
LRQRD	**[M53]**	9.66	0.81	0.11	2.1-2.6	16.69	0.14	119	9.19	<0.0001
	[F80]	12.03	0.8	0.09						
LUQRD	**[M53]**	9.98	0.84	0.12	1.9-2.5	15.37	0.14	161	9.01	<0.0001
	[F80]	12.15	0.76	0.09						
RIQRD	**[M53]**	10.08	0.73	0.1	1.9-2.4	16.15	0.13	131	9.14	<0.0001
	[F80]	12.21	0.76	0.08						
RRQRD	**[M53]**	9.62	0.81	0.11	2.1-2.7	0.14	11.42 13.28	120	9.19	<0.0001
	[F80]	12.03	0.81	0.09						
RUQRD	**[M53]**	9.91	0.86	0.12	1.9-2.5	15.59	0.15	157	9.02	<0.0001
	[F80]	12.16	0.79	0.09						

LIQRD, Left Inferior Quadrant Ridge Density; LRQRD, Left Radial Quadrant Ridge Density; LUQRD, Left Ulnar Quadrant Ridge Density; RIQRD, Right Inferior Quadrant Ridge Density; RRQRD, Right Radial Quadrant Ridge Density; RUQRD, Right Ulnar Quadrant Ridge Density; S.D., Standard Deviation; CI.95, 95% Confidence interval; SED, Standard Error of Difference, SEM, Standard Error of the Mean

Table 3- *Statistical findings on ridge density (ridges/25mm²) (quadrant wise).*

Gender[n]	Mean	S.D.	SEM	CI.95	t-value	SED	U-value	Z-Score	p-value
[M53]	9.89	0.81	0.05	2.1-2.4	39.12	0.06	5079	22.35	<0.0001
[F80]	12.13	0.78	0.04						

S.D., Standard Deviation; SEM, Standard Error of Mean; CI.95, 95% Confidence interval; SED, Standard Error of Difference

Table 4- *Sex wise distribution of fingerprint ridge density (ridges/25mm²) throughout the quadrants.*

Ridge Density (ridges/25mm²)	Male		Female	
	n	%	n	%
8	1	1.9%	0	0
9	7	13.2%	0	0
10	32	60.4%	1	1.25%
11	12	22.6%	12	15%
12	1	1.9%	37	46.3%
13	0	0	29	36.3%
14	0	0	1	1.25%
Total	53	100%	80	100%

density values based on Baye's theorem [9]. LR for males decreased drastically from 48.3 to 1.5 between 10 and 11 RD, whereas in females, LR increased drastically from 0.7 to 24.4 between 11 and 12 RD, showing that RD of ≤10 ridges/ 25 mm² is more likely a male, and ≥12 ridges/25 mm² is more likely a female.

4. Discussion

In a study by Oktem et al. [8], ridge density (RD) ranged from 6 to 23 ridges/25 mm² when compared to the present study, wherein the range was 8 to 14 ridges/25 mm². However, in that study, RD in ulnar and radial areas of the fingerprints was significantly greater than the lower area when compared to the present study, wherein only males had significant higher RD in the inferior region when compared to the other two regions. Oktem et al. studied 3 regions in all the fingers [8]. Chauhan et al. reported a RD of ≤11 ridges/ 25 mm² for males, and ≥13 ridges/25 mm² for females [10]. The present study reports a RD of ≤10 ridges/ 25 mm² for males, and ≥11 ridges/25 mm² for females. However, the study by Chauhan et al. was not quadrant specific; and the method adopted (latent fingerprints were obtained and later developed using black powder) in that study was complicated. Based upon our results, the author believes that the present study methodology (patent thumbprints by ink staining method) is more reliable,

convenient and economical for analysing and documentation purposes. Vinod et al. reported a RD of ≤12 ridges/25 mm^2 for males, and ≥13 ridges/25 mm^2 for females in the Chinese population, and a RD of ≤11 ridges/25 mm^2 for males, and ≥13 ridges/25 mm^2 for females in the Malaysian population [11].

Kahdri et al., in their study on rolled fingerprints, reported mean ridge density (MRD) of 12.4 ridges/25 mm^2 for male and 12 ridges/25 mm^2 for female [12]. The present study reports MRD of 9.89 ridges/25 mm^2 for male and 12.13 ridges/25 mm^2 for female. Also, the present study used plain thumbprints. Rolled fingerprints are obtained by rolling a finger from one side to the other in order to capture all of the ridge details of a finger. Plain impressions are those in which the finger is pressed down on a flat surface but not rolled. Plain impressions cover a smaller area than rolled prints. However, rolled fingerprints have a major drawback, which is distortion introduced during rolling [13]. Gungadin reported a MRD of 12.8 ridges/25 mm^2 for males and 14.6 ridges/25 mm^2 for females, wherein the upper portion of the radial border of each of 10 plain fingerprints was studied [14]. Gungadin believed that all fingerprint patterns show a similar ridge flow in this region. Kumar et al. reported a higher MRD of 14.8 ridges/25 mm^2 for females, and 11.9 ridges/25 mm^2 for males [15]. Different methodologies adopted, and ethnic and geographic variations are responsible for differences in results reported by various authors (Table- 5).

The author of the present study believes that the ridges are less coarse in females, which is why they have higher RD. Coarseness of a ridge is termed as ridge breadth. Ridge breadth (RB) is defined as the distance between the center of one epidermal furrow and the center of the next furrow along a line at right angles to the direction of the furrows [16]. This definition refers to blue/black ink fingerprints on a white paper, as in the present study. Kralik and Novotny reported age related differences in mean RB, wherein mean RB under 0.39 mm signified an individual less than 15 years of age, and the mean RB values over 0.52 mm signified a full grown adult male [16]. They also reported a 9% difference in ridge breadth between males and females, and the consequent increment in RD was attributed to the number of X-chromosomes [16]. However, Penrose and Loesch stated that RB has a direct relation to the number of sex chromosomes, wherein, Y-chromosome affects the ridge breadth more than the X-chromosome

Table 5- *Findings on fingerprint ridge density among males and females reported in various studies.*

Reference	Population/Ethnic group	Ridge density (ridges/25mm²)	
		Male	Female
Chauhan et al. [10]	North India	≤11	≥13
Vinod et al. [11]	Chinese	≤12	≥13
Vinod et al. [11]	Malaysian	≤11	≥13
Kumar et al. [15]	Uttarakhand, India	≤12	≥14
Present study	Indian Tamil	≤10	≥11

[17]. Indeed, narrowest RB was observed in patients with Turner's syndrome (X), while XYY males had the widest [18]. Cummins et al. were the first to present extensive reports on dimensions and sex related differences in RB. They reported a ridge breadth (RB) of 0.48 mm for males and 0.43 mm for females [19-20]. Earlier studies on Polish children have reported that there is no significant difference in RB between males and females up to the age of 12 years, whereas in older children, the difference between the two sexes is significant. Also, the ridges are not age dependent and do not change unless affected by injury. However, the ridges do grow further apart with an increasing age as the body size increases [21-23]. Gutierrez-Redomero et al. [24] stated that epidermal RB varies considerably among different dermatoglyphic topological regions and between the genders. Also, there is a relationship between RB and hand size, which means that males, by the virtue of larger hand size, have higher RB and lower RD. For the same reason, the author of the present study believes that RD of the thumb is lower, by virtue of its larger size, compared to the other fingers in a given population. Therefore, RD for the thumb should be analysed and reported separately, which is why thumbprints were specifically considered for the present study. None of the previous studies reported results specific for the thumb.

The is hoped that the results will be beneficial for law enforcement authorities in identifying gender from thumbprints. Also, the present study gives scope for further research on sex differences in ridge breadth of a patent thumbprint.

5. Conclusion

In the present study, loop pattern was found in 56% of thumbprints, whorl pattern in 32.7%, arch in 8.7% and composite pattern was found in 2.6% of thumbprints. Sex difference in thumbprint ridge density was significant. Thumbprint ridge density, throughout the quadrants, ranged from 8-12 ridges/25 mm^2 in males, and from 10-14 ridges/ 25 mm^2 in female participants. It was inferred that ridge density of ≤10 ridges/25 mm^2 is male, and ≥11 ridges/25 mm^2 is female. Difference in ridge density of left and right thumbprints was not significant (p-value 0.8754), which meant that ridge density of the left thumb of an individual can be considered similar to that of that right thumb in all quadrants. Difference in ridge density of fingerprint patterns was also not significant at $p < 0.05$, showing that fingerprint patterns do not play a significant role in thumbprint ridge density.

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Ethical approval

Study was approved by the Institutional Ethics Committee (VMCIEC/44/2017)

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Conflict of interest

None.

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