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Short paper

Is fingerprint ridge density influenced by hand dimensions?

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Abstract. *Background and aim:* The technology of fingerprinting has revolutionized the forensic identification process. Following its initial introduction in the first quarter of the twentieth century, various aspects of fingerprint were extensively explored. However, the correlation between fingerprint ridge density and hand dimensions has not yet been documented. Therefore, the present study has investigated the relationship so that some conclusions regarding the association can be established. *Methods:* The study included 500 subjects (250 males and 250 females) between the ages of 18 to 25 years who belong to the *Rajput* community of the Shimla and Solan districts of the Himachal Pradesh state of North India. The sexual dimorphism among the ridge count was examined using a student's t-test. The relationship of fingerprint ridge density with hand dimensions among both sexes and pooled data was analyzed using Pearson's correlation coefficient. *Results:* All the fingers on both hands showed statistically significant sex differences. When all digits were considered together, the left little finger in males and the right middle finger in females showed a weak but significant correlation with hand length while all the digits when considered in combination reported a strong correlation between hand length measurements. Similarly, the right thumb showed a significant correlation with handbreadth. All ten digits showed a highly significant correlation with hand breadth when pooled data was examined. *Conclusion:* The ridge density correlates with the hand dimensions in the case of pooled data. This relationship can then be used to devise prediction equations for hand dimensions based on ridge density, or vice-versa for pooled data. The equations will also help in estimating hand dimensions based on ridge density and vice-versa (www.actabiomedica.it)

Keywords: Fingerprint ridge density, Hand dimensions, Identification, Biological anthropology

Introduction

The skin at the anterior side of the hands has specialized frictional ridges with evolutionary significance. During the gestational period, the basal layer grows faster than the epidermal layer, resulting in folds in the basal layer that are completely arbitrary. The folding process is also affected by the shape and size of the blood vessels. These creases become evident at the epidermis after 17 weeks, and the fingerprints become permanent i.e., they remain unaltered until the death of an individual (1,2). Consequently, it is claimed that they are unique to an individual and hence have forensic significance.

The impressions left by the frictional ridges are recognized as prints, whereas fingerprints are the impressions left by fingers (3). Fingerprints have played a significant role in personal identification and are known as "the golden standard" in terms of profiling and identification (4). Fingerprints are studied on three different levels: the first, second, and third levels. Only the fingerprint patterns and ridge count of the fingerprint pattern are studied at the first level, the minutiae of the fingerprints are examined at the second level, and microscopic features such as pores, line shape, incipient ridges, creases, and so on are observed at the third level. As we progressed from the first level

to the third level, the individualistic properties of the fingerprints became more pronounced. Therefore, the minutiae, pores, line shape, and so on are the unique characteristics of fingerprints. Genetic and environmental factors have a large influence on the development of these unique characteristics of fingerprints (5).

The present study has been conducted on an important aspect of fingerprints i.e. fingerprint ridge density. The number of ridges on a fingerprint per unit area is defined as its ridge density (6). The ridge density varies with age, sex, and population as suggested in the literature (7-10). For example, males always have less ridge density than females, ridge density decreases with age, and so on.

Hand dimensions are required to be keenly considered as the major influencing factor while determining the fingerprint ridge density for personal identification and primarily during sex estimation as the hand provides the platform for the formation of ridges and furrows. Larger dimensions of the hand provide greater surface area for the development of finger ridges and furrows. This concept has been taken up as a research problem in the present study to find out whether the fingerprint ridge density varies with the hand dimensions or not.

Sexual dimorphism is very predominant in hand dimensions (11,12). Males show larger hand dimensions (hand length and hand breadth) than females which ultimately results in greater ridge width in males and thus may have some role in fingerprint ridge density which the present study focuses on. Larger body proportions in males as compared to females and their relationship with fingerprint ridge density have been reported by Mundorff et al. (9). However, no study on the relationship between fingerprint ridge density and hand dimensions has been reported to date. Thus, this study will be the prime study in this regard.

Materials and methods

Subjects

The present study was carried out in the districts of Shimla and Solan of Himachal Pradesh state of North India. A total of 500 subjects (250 males and 250 females) within the age range of 18 to 25 years and belonging to the *Rajput* community of the Shimla and Solan districts were included in the study. Subjects with a previous history of hand or forelimb trauma, skin diseases, congenital anomalies, or who have undergone recent surgery were not included in the study.

Ethical permission

The consent of the subjects was taken before the data collection. The informed written consent form was filled out by the individuals willing to participate after assuring them that all the information collected would be kept confidential. The ethical permission for conducting this study was obtained from Panjab University Institutional Ethical Committee vide letter no. PUIEC/2016/51/51-A//15/06, dated 12.09.2016.

Methodology

The fingerprints were obtained from both hands of each subject. The standard procedure for recording the fingerprints was followed from Cummins and Midlo (13). Moreover, two anthropometric measurements of hands were included in the study as followed from Singh and Basin (14).

1. *Hand length:* It is the direct distance measured from top most point of the middle finger to the midpoint of the distal crease of the wrist.
2. *Hand-breadth:* It is the maximum breadth of the hand measured from the second to the fifth metacarpal with the fingers joining the palm.

Determination/calculation of fingerprint ridge density

Fingerprint ridge density (FPRD) in each fingerprint was determined by counting the number of ridges falling in a 25 X 25mm square space within a predetermined location on the fingerprint, according to the method described by Acree (15). The ridge density was counted thrice in different regions of the fingerprint (radial, ulnar and proximal) and the mean was considered as the actual fingerprint ridge density.

Statistical analysis

The normality of the data was checked and the data was found to be normally distributed. The sexual dimorphism among the ridge count was checked using the student's t-test. Further, the relationship of fingerprint ridge density with hand dimensions among both sexes and pooled data was analyzed using Pearson's correlation coefficient using IBM SPSS (Statistical product for service solution, version 21).

Results

The statistically significant variations in the fingerprint ridge density among both male as well as female subjects were reported in the present population (Table 1). The highest variability was observed in the left ring and left index finger (t = 13.794, 13.423 respectively) while the lowest significance was observed in the right ring and left thumb (t = 8.132, 8.882 respectively) (Table 1).

Table 2 depicts Pearson's correlation coefficient (r) pertaining to fingerprint ridge density concerning hand length and a handbreadth. The left little finger in males (r = 0.206, p = 0.040) and right middle finger in females (r = 0.202, p = 0.43) showed a weak but significant correlation with hand length while all the digits when considered in combination reported a strong correlation (p = 0.00) hand length measurement (Table 2). Similarly, when Pearson's correlation coefficient (r) of fingerprint ridge density was examined with hand breadth, the right thumb showed a significant correlation with hand breadth (r = 0.218, p = 0.030) (Table 2). All ten digits showed a highly significant correlation with hand breadth when pooled data were examined (Table 2).

The correlation between the hand dimensions and ridge density is approximately found to be 0.5, which is considered a moderate correlation. Therefore, it can be stated that the ridge density is correlating with the hand dimensions in the case of pooled data. This relationship can be further used to devise prediction equations for hand dimensions based on ridge density or vice-versa for pooled data. The equations will further help in the estimation of hand dimensions based on ridge density or vice-versa.

Discussion

Many authors have studied dermatoglyphic parameters and features pertaining to hands and feet worldwide, considering features like finger ridge characteristics, ridge count, pattern types, fingerprint, palm print, fingerprint ridge density, palm print ridge

Table 1. Ridge count of males and females along with sex differences.

Sr. No.	Ridge count	Males (N= 250)		Females (N= 250)		*t–value*	*p*-value
		Mean (cm)	Standard deviation (cm)	Mean (cm)	Standard deviation (cm)		
1.	**Left thumb**	13.22	1.24	15.00	1.58	8.882	0.000
2.	**Left index finger**	12.79	1.16	15.06	1.23	13.423	0.000
3.	**Left middle finger**	13.13	1.16	15.08	1.11	12.183	0.000
4.	**Left ring finger**	12.58	1.33	14.80	0.91	13.795	0.000
5.	**Left little finger**	13.18	1.10	14.91	1.10	11.149	0.000
6.	**Right thumb**	13.39	1.36	15.01	1.22	8.898	0.000
7.	**Right index finger**	12.93	0.90	14.85	1.38	11.639	0.000
8.	**Right middle finger**	13.37	1.14	15.12	1.21	10.548	0.000
9.	**Right ring finger**	13.70	1.21	14.94	0.94	8.132	0.000
10.	**Right little finger**	12.77	1.29	14.91	1.07	12.738	0.000

Table 2. Pearson Correlation coefficient (r) between fingerprint ridge density with Hand length and Hand breadth.

Parameters	Sex	Hand Length		Hand Breadth	
		Correlation coefficient (r)	p-value	Correlation coefficient (r)	p-value
Left thumb	**Females**	0.149	0.139	-0.071	0.483
	Males	0.116	0.251	0.150	0.138
	Total	-0.306**	0.000	-0.383**	0.000
Left index finger	**Females**	0.089	0.378	0.069	0495
	Males	0.137	0.173	-0.028	0.782
	Total	-0.436**	0.000	-0.504**	0.000
Left middle finger	**Females**	-0.024	0.811	0.083	0.409
	Males	0.026	0.794	0.099	0.327
	Total	-0.466**	0.000	-0.486**	0.000
Left ring finger	**Females**	-0.027	0.791	0.047	0.645
	Males	0.145	0.151	-0.072	0.478
	Total	-0.460**	0.000	-0.534**	0.000
Left little finger	**Females**	0.178	0.076	0.189	0.059
	Males	0.206*	0.040	0.026	0.797
	Total	-0.339**	0.000	-0.430**	0.000
Right thumb	**Females**	0.115	0.253	0.218*	0.030
	Males	0.098	0.330	0.017	0.865
	Total	-0.320**	0.000	-0.365**	0.000
Right index finger	**Females**	0.114	0.260	0.037	0.715
	Males	0.189	0.060	0.012	0.902
	Total	-0.381**	0.000	-0.495**	0.000
Right middle finger	**Females**	0.202*	0.043	-0.018	0.856
	Males	-0.001	0.990	0.089	0.377
	Total	-0.378**	0.000	-0.412**	0.000
Right ring finger	**Females**	0.045	0.654	-0.023	0.822
	Males	-0.068	0.502	0.073	0.468
	Total	-0.373**	0.000	-0.380**	0.000
Right little finger	**Females**	-0.022	0.828	-0.014	0.889
	Males	-0.008	0.935	-0.060	0.552
	Total	-0.487**	0.000	-0.524**	0.000

*p<0.05, **p<0.01

density, footprints, and so on (8,16-19). The literature also suggests that dermatoglyphics can be used as a diagnostic tool to evaluate the state of health of an individual (20-25). Certain investigations have found that the peculiarities of dermatoglyphic patterns have played an important role in the early detection of various diseases (21-23). In the instance of multiple sclerosis patients, the a-b ridge count and total ridge count were observed to be raised in all fingers (21) and the frequency of whorl patterns, high A-B ridge count, and 'atd' angles can aid in the diagnosis of coronary heart disease (22). Similarly, the early diagnosis of the

growth of a pituitary tumor can also be determined by dermatoglyphic features (23). However, some research has also produced conflicting findings, suggesting that there is no correlation between dermatoglyphic patterns and autistic disorder (20), type 2 diabetes mellitus (26), or breast cancer (24). This is also one of the important aspects to be discussed here.

Moreover, fingerprint ridge density and its characteristics regarding sex determination, bilateral variability, individuality among both hands of the same person, and variation in fingerprints of two different fingers of the same hand have also been reported in different studies conducted in the past (6,8,9,13,15,17,27). However, not much work has been reported on the relationship of fingerprint ridge density with hand dimensions particularly hand length and hand breadth which can be employed as a clue to personal identification in forensic examinations. The current study is the pioneer study in this aspect where the correlation between fingerprint ridge density and hand dimensions has been taken into account in an Indian context. The results obtained in the present study reported a weak but significant correlation between fingerprint ridge density and hand breadth as compared to hand length with left-hand digits being more positively correlated with fingerprint ridge density than right-hand digits. This can be attributed to a direct effect of the ridge breadth on the width of a hand. Ridge breadth in males has been reported to be greater than in females (6,7,17,19).

When compared to hand length, the fingerprint ridge density seems to have a strong correlation with hand breadth in both males and females. The data demonstrate that females tend to have greater ridge density than males, due to smaller ridge breadth in females as compared to males. Moreover, the fingerprint ridge density is more closely correlated with the hand dimensions in the case of pooled data. This relationship can be further used to devise prediction equations for hand dimensions based on ridge density or vice-versa for pooled data. Additionally, the equations will be useful for estimating hand dimensions based on ridge density or vice-versa.

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Availability of Data and Materials: The study is a part of a Ph.D.'s project and the raw data is available with one of the authors (SS) who has been nominated as a guarantor for the work. SS accepts full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

References

1. Mulvihill JJ, Smith DW. The genesis of dermatoglyphics. J Pediatr 1969;75(4):579-89.
2. Babler WJ. Quantitative differences in morphogenesis of human epidermal ridges. Birth Defects Orig Artic Ser 1979;15(6):199-208.
3. Dayal MR, Spocter MA, Bidmos MA. An assessment of sex using the skull of black South Africans by discriminant function analysis. HOMO 2008;59:209–21.
4. Meuwly D. Forensic Use of Fingerprints and Fingermarks. In: Li S, Jain A, editors. Encyclopedia of Biometrics. Boston, MA: Springer; 2014.
5. Wertheim K. Embryology and morphology of friction ridge skin. The Fingerprint Sourcebook; 2011. p. 103-26.
6. Gutiérrez-Redomero E, Alonso C, Romero E, Galera V. Variability of fingerprint ridge density in a sample of Spanish Caucasians and its application to sex determination. Forensic Sci Int 2008;180(1):17-22.
7. Nithin MD, Manjunatha B, Preethi DS, Balaraj BM. Gender differentiation by finger ridge count among South Indian population. J Forensic Leg Med 2011;18(2):79-81.
8. Krishan K, Kanchan T, Ngangom C. A study of sex differences in fingerprint ridge density in a North Indian young adult population. J Forensic Leg Med 2013;20(4):217-22.
9. Mundorff AZ, Bartelink EJ,Murad TA. Sexual dimorphism in finger ridge breadth measurements: A tool for Sex Estimation from fingerprints. J Forensic Sci 2014;59(4): 891-7.
10. Rivalderia N, Sanchez-Andres A, Alonso-Rodriguez C, Dipierri JE, Gutierrez-Redomero E. Fingerprint ridge

density in the Argentinean population and its application to sex inference: a comparative study. HOMO 2016;67:65–84.
11. Kanchan T, Rastogi P. Sex determination from hand dimensions of North and South Indians. J Forensic Sci 2009;54(3): 546-50.
12. Jee SC, Bahn S, Yun MH. Determination of sex from various hand dimensions of Koreans. Forensic Sci Int 2015;257: 521.e1-521.e10.
13. Cummins H, Midlo C. Finger prints, palms and soles: an introduction to dermatoglyphics. New York: Dover Publications;1961.
14. Singh IP, Bhasin MK, Anthropometry, Kamla-Raj Enterprises: Delhi;1968.
15. Acree MA. Is there a gender difference in fingerprint ridge density? Forensic SciInt1999;102(1):35-44.
16. Krishan K, Ghosh A, Kanchan T, Ngangom C, Sen J. Sex differences in fingerprint ridge density-causes and further observations. J Forensic Leg Med 2010;17(3):172-3.
17. Agnihotri AK, Jowaheer V, Allock A. An analysis of fingerprint ridge density in the Indo-Mauritian population and its application to gender determination. Med Sci Law 2012;52(3):143-7.
18. KanchanT, Krishan K, Aparna KR, Shyamsundar S. Is there a sex difference in palm print ridge density?. Med Sci Law 2013;53(1):33-9.
19. Eshak GA, Zaher JF, Hasan EI, El-Azeem Ewis AA. Sex identification from fingertip features in Egyptian population. J Forensic Leg Med 2013;20:46–50.
20. Milicić J, Bujas Petković Z, Bozikov J. Dermatoglyphs of digito-palmar complex in autistic disorder: family analysis. Croat Med J 2003;44(4):469-76.
21. Sabanciogullari V, Cevik S, Karacan K, Bolayir E, Cimen M. Dermatoglyphic features in patients with multiple sclerosis. Neurosciences (Riyadh) 2014;19(4):281-5.
22. Lu H, Qian W, Geng Z, Sheng Y, Yu H, Ma Z, Huo Z. Dermatoglyphs in Coronary Artery Disease Among Ningxia Population of North China. J Clin Diagn Res 2015;9(12):AC01-4.
23. Gradiser M, Matovinovic Osvatic M, Dilber D, Bilic-Curcic I. Assessment of Environmental and Hereditary Influence on Development of Pituitary Tumors Using Dermatoglyphic Traits and Their Potential as Screening Markers. Int J Environ Res Public Health 2016;13(3):330.
24. Mušanović J, Metović A, Husremović F, Bejić S, Hasković A, Babić A, Šljuka S. Digital dermatoglyphics in the evaluation of the genetic basis of breast cancer in Bosnian-Herzegovinian population - quantitative analysis. Med Glas (Zenica) 2020;17(1):1-6.
25. Patil V, Ingle DR. An association between fingerprint patterns with blood group and lifestyle based diseases: a review. Artif Intell Rev 2021;54(3):1803-1839.
26. Jeddy N, Radhika T, Sai Lakshmi LJ, Khodabux RJ, Srilekha R, Sruthi G. Cheiloscopy and dermatoglyphics as screening tools for type 2 diabetes mellitus. J Forensic Dent Sci 2019;11(3):163-166.
27. Kralik M, Novotny V. Epidermal ridge breadth: an indicator of age and sex in paleodermatoglyphics. Variab Evol 2003;11:5–30.

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