DOI: 10.7860/JCDR/2023/63632.18026

Original Article

Anatomy Section

Qualitative Analysis of the Right Plantar Dermatoglyphic Configurations in Himachal Pradesh, India: A Dimorphic Study

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ABSTRACT

Introduction: Dermatoglyphics is defined as the study of the configurations on the plantar aspect of the feet and the palmar aspect of the hands. It is a well established fact that these epidermal configurations are distinct for each and every individual.

Aim: To study and analyse the plantar dermatoglyphic patterns on the right sole of the individuals of Himachal Pradesh and to know its implication in gender determination.

Material and Methods: This cross-sectional study was conducted in the Department of Anatomy, Adesh Institute of Medical Sciences, Bathinda, Punjab, India, and the data was collected over a period of one year (May 2021 to May 2022). The sole dermatoglyphic prints of 400 individuals (200 males and 200 females) of the age group 18-45 years without any known medical conditions were analysed for the dermatoglyphic patterns visualised in the Hallucal/Thenar/First Interdigital Area (Rt Th/H/ID1), Second Interdigital Area (Rt ID2), Third Interdigital Area (Rt ID3), Fouth Interdigital Area (Rt ID4), Hypothenar Distal Area (Rt HTD), Hypothenar Proximal Area (Rt HTP) and the Calcar Area (Rt C) of the right sole. The findings thus obtained were then subjected to Chi-square test using the Statistical Package for the Social Sciences (SPSS) version 21.0 software.

Results: The mean age of the subjects included in the study was 29±4 years and 16±7 years for 200 Himachali males and 200 Himachali females, respectively. The study showed that there was indeed an association between the right plantar dermatoglyphic patterns and the sex of the people belonging to Himachal Pradesh, India. The results suggest that the distribution of the dermatoglyphic patterns on Rt Th/H/ID1 of the females was significantly different from the males (p-value <0.05). On the Rt ID2, Rt ID3 and Rt ID4, the differences observed between the females and males were highly significant (p-value <0.001) whereas on the Rt HTD, Rt HTP and the Rt C, all the males and females depicted a lack of pattern.

Conclusion: The results of this investigation suggest that there exist some significant differences between the male and female subjects of Himachali population. The plantar dermatoglyphic patterns could therefore be utilised as an important tool to determine the gender of an individual in forensic and medico-legal aspects as well as to determine the relationship of an individual to an ethnic group based in different geographical areas.

Keywords: Arch, Loop, Sole, Whorl

INTRODUCTION

Dermatoglyphic is a term formed by the union of two words, 'Derma' which means skin and 'glyphics' which refers to carving [1]. Dermatoglyphics is defined as the study of the configurations formed by the ridges of the palm and sole of the hands and feet respectively. It is a well established fact that these epidermal ridges which lead to the formation of a distinct pattern are a characteristic feature of any individual [2-5]. Since a long time, these epidermal ridges have been used by fortune tellers to predict the future but it was only in the seventeenth centaury that this technique was put to a scientific use by an anatomist Midlo [6]. This term "Dermatoglyphics" basically came into existence in 1926 and was coined by Harold Cummins. After this, the pool of the information kept on increasing as the time passed by with the contributions from various researchers in the field of anthropology as well as medicine [7]. Now-a-days, dermatoglyphics has been recognised as a potent tool in medico-legal, genetic as well as anthropological studies [8]. Dermatoglyphics also plays a significant role in determining the ethnic affinities and the ethnic variation among different populations [9].

The formation of the epidermal ridges begins early in the foetal life. It begins at about 12th week of gestation and continues upto 19th week. It has been observed that the formation of the plantar epidermal ridge patterns is preceded by the formation of the palmar ridge patterns. These dermatoglyphic configurations are determined by hereditary but they are also influenced by various environmental factors in the womb. These patterns, once formed do not change throughout the entire life of a person [8]. This can be proven by the fact that the dermatoglyphic prints are not similar even among the monozygotic twins. This scientific characteristic of these dermatoglyphic patterns is utilised in medicine to solve the questioned paternity issues and diagnosing various congenital genetic disorders [9-11]. On a histologic view, the skin on the palms and soles is characterised by a thick cornfied layer with prominent papillae, numerous nerve endings and eccrine sweat units and the lack of hair follicles [12-15].

Although a lot of researchers have previously worked on palmar dermatoglyphic patterns among various populations, plantar dermatoglyphic patterns have always been neglected [16-20]. This study has been undertaken to know the implications of plantar dermatoglyphic patterns in sexual dimorphism among the Himachali population.

MATERIALS AND METHODS

This cross-sectional study was carried in the Department of Anatomy, Adesh Institute of Medical Sciences, Bathinda, Punjab, India and the data was collected over a period of one year (May 2021 to May 2022). Dermatoglyphic prints of the right sole of randomly selected 400 healthy subjects (200 males and 200 females) belonging to the state of Himachal Pradesh were taken. Informed consent and Institutional Ethics Committee (IEC) clearance (AU/EC/FM/2021/192) were obtained before the study was carried out.

Inclusion criteria: All the healthy individuals residing in the state of Himachal Pradesh within the age group 18-45 years. Only

those subjects were included who were willing to participate in the study.

Exclusion criteria: Individuals with absence of a digit of any foot. Individuals with any condition/deformity of feet which could interfere with the recording of the foot prints.

Sample size estimation: Sample size was estimated from formula without finite population correction calculated according to Daniel WW (1999) [21]:

$$n=\frac{Z^2p(1-p)}{d^2}$$

$$n=\frac{(1.96)^2(0.5)(1-0.5)}{(0.05)^2}=384$$

n=sample size

Z=the standard deviate usually 1.96 which corresponds to 95% confidence level

P=expected prevalence or proportion=0.5

d=Degree of accuracy usually (0.05);

400 subjects were taken for the study.

Materials required were [Table/Fig-1]:

- Black or blue duplicating ink
- Rubber roller
- Porcelain tile
- Pen and pencil
- Cotton puffs
- Magnifying lens
- Scale
- Needle with a sharp point for ridge counting

[Table/Fig-1]: Materials require for taking the dermatoglyphic prints.

Methodology: Dermatoglyphic prints were taken by the ink and roller method as described by Cummins [22]. Informed consent was taken from all the individuals before taking any prints. The procedure was as follows [Table/Fig-2]:

- Before the procedure, to get rid of any dirt, the subjects were asked to wash their feet with soap and water.
- After that, their foot was coated with black or blue duplicating ink with the help of rubber roller. Then, their foot was pressed against the white bond paper which was kept over the porcelain tile.
- The same procedure was repeated with the other foot on another sheet of paper.
- The final foot print was thus obtained [Table/Fig-3].

The foot prints taken were then observed with the help of a magnifying glass for different dermatoglyphic patterns on the sole which was divisible into various areas: Rt Th/H/ID1, Rt ID2, Rt ID3, Rt ID4, Rt HTD, Rt HTP and Rt C [Table/Fig-4] [22].

[Table/Fig-2]: A step by step procedure of obtaining the plantar dermatoglyphic prints.

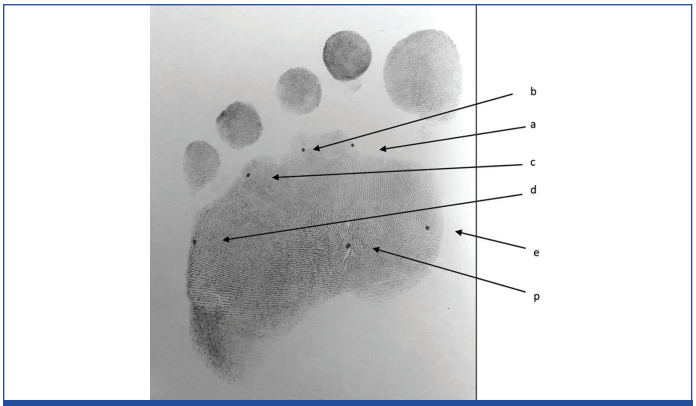
[Table/Fig-3]: A foot print taken by ink and roller method depicting the various patterns on the sole.
[Table/Fig-4]: Topography of the plantar configurational areas [22]. (Images from left to right)

The areas studied on the soles are as follows [Table/Fig-4] [22]:

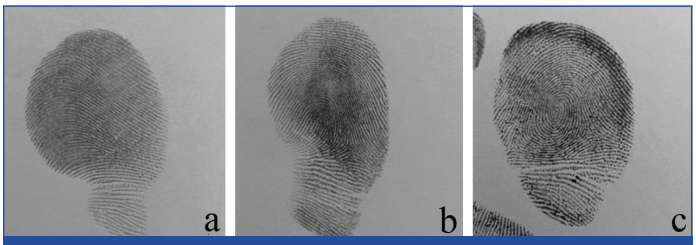
1. **Hallucal area:** This is the combination of distal thenar and the first interdigital area. It covers the tibial area of the ball of the foot.
2. **Interdigital areas:** These are homologous to those found on the hand. Because, the first interdigital area belongs topographically to the hallucal area, there are usually only three interdigital areas identified on the distal area of the sole, labeled usually II, III and IV. Areas II-IV are bordered by plantar digital triradii a and b, b and c, and c and d, respectively [Table/Fig-5].
3. **Hypothenar area** covers the fibular side of the sole between the interdigital areas and the heel and it is further divided into hypothenar proximal and Rt HTDs.
4. **Calcar area** occupying the heel of the foot is mostly devoid of any pattern. This kind of presentation is known as open fields. True patterns rarely occur.

Patterns studied [Table/Fig-6,7] [22]:

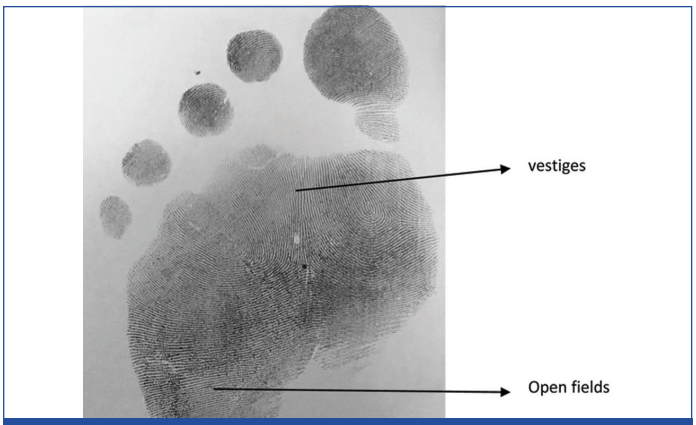
1. **Arches:** The ridges entering from one side of the area and leaving from the other.
2. **Loop:** Tibial, fibular, proximal and distal loop depending on the opening of the loop.
3. **Whorls:** The ridges spiraling on themselves.
4. **Vestiges:** These do not represent true patterns but consists usually of a series of straight parallel converging ridges having a direction different from the neighbouring ridged area. They are basically ridge disarrangement.
5. **Open fields:** These are the most common ridges configuration encountered in the proximal areas of the sole. These are pattern less areas which are formed by almost parallel ridges.



[Table/Fig-5]: The triradii in the sole depicting the five digital triradii and one axial triradius where a,b,c,d and e represent the digital triradii and p is the axial triradius.



[Table/Fig-6]: The three basic patterns visualised on the sole: a) Arch; b) Loop; c) Whorl.



[Table/Fig-7]: Vestiges and open fields as visualised on the sole.

STATISTICAL ANALYSIS

The data thus obtained was then subjected to statistical analysis using the SPSS 21.0 software. Chi-square test was used to analyse these findings. A p-value <0.05 was considered to be statistically significant.

RESULTS

The mean age of the subjects included in the study was 29±4 years and 16±7 years for 200 Himachali males and 200 Himachali females, respectively.

When observed on the Rt Th/H/ID1, females showed 0.5% arches, 12.5% whorls, 65.0% distal loops, 11.5% tibial loops, 8% vestiges, 2.5% open fields and no proximal loops whereas the males had 11.0%, whorls, 77.5% distal loops, 0.5% proximal loops, 2.0% tibial loops, 6.5% vestiges, 2.5% open fields and no arches. The distribution of patterns in this area is significantly different between the males and females (p-value=0.006) [Table/Fig-8].

On the Rt ID2 area, the females showed no arches, 1.0% whorls, 6.5% distal loops, 23.0% proximal loops, 69.5% open fields and no tibial loops as well as vestiges whereas males showed 8.5% distal loops, 60.5% proximal loops, 0.5% vestiges, 30.5% open fields and zero arches as well as tibial loops. The distribution of patterns between the males and females in this area was highly significant (p-value <0.001) [Table/Fig-9].

On the Rt ID3 area, it was observed that the females had no arches, 0.5% whorls, 27.0% distal loops, 17.0% proximal loops, 2.0% vestiges, 53.5% open fields and no tibial loops whereas the males showed 52.5% distal loops, 19.0% proximal loops, 1.0% vestiges, 27.5% open fields and zero arches as well as tibial loops. The distribution of patterns between the males and females in this area was highly significant (p-value <0.001) [Table/Fig-10].

Rt Th/H/ID1		Gender		Total	χ^2 value (p-value)
		Female	Male		
Arch	Count	1	0	1	18.07 (0.006)*
	% within Gender	0.5%	0	0.3%	
Whorl	Count	25	22	47	
	% within Gender	12.5%	11.0%	11.8%	
Distal loop	Count	130	155	285	
	% within Gender	65.0%	77.5%	71.3%	
Proximal loop	Count	0	1	1	
	% within Gender	0	0.5%	0.3%	
Tibial loop	Count	23	4	27	
	% within Gender	11.5%	2.0%	6.8%	
Vestiges	Count	16	13	29	
	% within Gender	8.0%	6.5%	7.2%	
Open fields	Count	5	5	10	
	% within Gender	2.5%	2.5%	2.5%	
Total	Count	200	200	400	
	% within Gender	100.0%	100.0%	100.0%	

[Table/Fig-8]: Comparative distribution and analysis of female and male subjects of hilly areas according to the type of pattern on Rt Th/H/ID1 using Chi-square test. p<0.05* statistically significant, p<0.001** statistically highly significant

Rt ID2		Gender		Total	χ^2 value (p-value)
		Female	Male		
Arch	Count	0	0	0	67.64 (<0.001)**
	% within Gender	0	0	0	
Whorl	Count	2	0	2	
	% within Gender	1.0%	0	0.5%	
Distal loop	Count	13	17	30	
	% within Gender	6.5%	8.5%	7.5%	
Proximal loop	Count	46	121	167	
	% within Gender	23.0%	60.5%	41.8%	
Tibial loop	Count	0	0	0	
	% within Gender	0	0	0	
Vestiges	Count	0	1	1	
	% within Gender	0	0.5%	0.3%	
Open fields	Count	139	61	200	
	% within Gender	69.5%	30.5%	50.0%	
Total	Count	200	200	400	
	% within Gender	100.0%	100.0%	100.0%	

[Table/Fig-9]: Comparative distribution and analysis of female and male subjects of hilly areas according to the type of pattern on Rt ID2 using Chi-square test. p<0.05* statistically significant, p<0.001** statistically highly significant

Rt ID3		Gender		Total	χ^2 value (p-value)
		Female	Male		
Arch	Count	0	0	0	34.94 (<0.001)**
	% within Gender	0	0	0	
Whorl	Count	1	0	1	
	% within Gender	0.5%	0	0.3%	
Distal loop	Count	54	105	159	
	% within Gender	27.0%	52.5%	39.8%	
Proximal loop	Count	34	38	72	
	% within Gender	17.0%	19.0%	18.0%	

Tibial loop	Count	0	0	0
	% within Gender	0	0	0
Vestiges	Count	4	2	6
	% within Gender	2.0%	1.0%	1.5%
Open fields	Count	107	55	162
	% within Gender	53.5%	27.5%	40.5%
Total	Count	200	200	400
	% within Gender	100.0%	100.0%	100.0%

[Table/Fig-10]: Comparative distribution and analysis of female and male subjects of hilly areas according to the type of pattern on Rt ID3 using Chi-square test.
p<0.05* statistically significant, p<0.001** statistically highly significant

On the Rt ID4 area, the females showed no arches as well as whorls, 14.0% distal loops, 2.0% proximal loops,1.5% vestiges, 82.5% open fields and no tibial loops whereas the males showed 32.5% distal loops, 2.5% proximal loops, 3.5% vestiges, 61.5% open fields and zero whorls, arches as well as tibial loops. The distribution of patterns between the males and females in this area was highly significant (p-value <0.001) [Table/Fig-11].

Rt ID4		Gender		Total	χ^2 value (p-value)
		Female	Male		
Arch	Count	0	0	0	22.56 (<0.001)**
	% within Gender	0	0	0	
Whorl	Count	0	0	0	
	% within Gender	0	0	0	
Distal loop	Count	28	65	93	
	% within Gender	14.0%	32.5%	23.3%	
Proximal loop	Count	4	5	9	
	% within Gender	2.0%	2.5%	2.3%	
Tibial loop	Count	0	0	0	
	% within Gender	0	0	0	
Vestiges	Count	3	7	10	
	% within Gender	1.5%	3.5%	2.5%	
Open fields	Count	165	123	288	
	% within Gender	82.5%	61.5%	72.0%	
Total	Count	200	200	400	
	% within Gender	100.0%	100.0%	100.0%	

[Table/Fig-11]: Comparative distribution of female and male subjects of hilly areas according to the type of pattern on Rt ID4 using Chi-square test.
p<0.05* statistically significant, p<0.001** statistically highly significant

Rt HTP, Rt HTD and the RT C areas showed equal distribution of males (200) and females (200) subjects in open fields and showed a lack of other patterns.

DISCUSSION

The epidermal ridge patterns on the palm and the sole are highly useful in biological studies [10]. The development of the epidermal ridges has been studied deeply in a series of light microscopic sections [23]. The embryogenesis of epidermal ridge patterns on the sole is said to be identical to that on palm with a single exception that each step occurs two or three weeks later [24]. Galton and Wilder were first to study about the hereditary basis of the establishment of dermatoglyphic patterns [25]. In 1968 Penrose LS and Loesch D published a memorandum on dermatoglyphic patterns reclassifying the basic patterns given by Galton [26,27]. Previously very few authors have made an attempt to study the plantar dermatoglyphic patterns. Penrose L and Loesch D; Schaumann B and Alter M were among those researchers. They were the first to establish the differences between the plantar dermatoglyphic patterns of males and females [28,29]. These differences could prove to be helpful in the identification of the remains during mass disaster cases and medico-legal investigations [29]. The author reports significant differences in the distribution of the dermatoglyphic patterns on the Rt Th/H/ID1 (p-value <0.05) between male and female subjects. On the Rt ID2, Rt ID3 and the Rt ID4, the differences observed between the females and males were highly significant (p-value <0.001) whereas on the Rt HTD, Rt HTP and Rt C, no difference was observed as all the subjects depicted open fields.

[Table/Fig-12] shows the comparison of the patterns on the hallucal area of the right sole in the study conducted by Schaumann B and Alter M, among the people of Oregon, USA, by Pawar among the people belonging to Loni, Maharashtra [29,30] and the present study. This shows that the present study and the study done by Pawar shows no arches in males and only 0.5% arches in females in the present study, but in another study arches were found to be 6.5% in males and 10% in the females [29,30]. This difference in the patterns was statistically significant. The present study showed the highest number of loops distal in this area among the males (77.5%) whereas in females it was only 65%. This difference was statistically significant whereas in the study by Pawar, males had 68% and females had 62% distal loops only [30]. This was not in accordance with the Schaumann B and Alter M study which showed more distal loops in females (60%) as compared to the males (54%) [29]. The number of tibial loops were more among females (11.5%) as compared to the males (2%) which was in accordance with the study conducted by Pawar (males 12%, females 14%) but this was not the case in Schaumann B and Alter M study (males 9.5%, females 8%) [29,30]. Schaumann B and Alter M found no vestiges among both males and females whereas in the study by Pawar, males had a higher number of vestiges as compared to the females. This was not the case with the present study which showed males having less vestiges as compared to the females. This difference was statistically significant. Whorls were seen 11% among the females and 12.5% among the males in the present study which was again in accordance with the study by Pawar (males 15%, females 21%) but differed with the findings of Schaumann B and Alter M which shows that males had 30% whorls as compared to the females which had only 22% whorls [29,30]. The differences which are visualised between the dermatoglyphic patterns in the

Pattern	Source	Males	Females
Arch	Present study	0	0.5%
	Study by Pawar RM and Pawar MN (2015) [30]	0	0
	Study by Schaumann B and Alter M, (1976) [29]	6.5%	10%
Distal loop	Present study	77.5%	65%
	Study by Pawar RM and Pawar MN (2015) [30]	68%	62%
	Study by Schaumann B and Alter M, (1976) [29]	54%	60%
Tibial loop	Present study	2%	11.5%
	Study by Pawar RM and Pawar MN (2015) [30]	12%	14%
	Study by Schaumann B and Alter M, (1976) [29]	9.5%	8%
Vestiges	Present study	6.5%	8%
	Study by Pawar RM and Pawar MN (2015) [30]	5%	3%
	Study by Schaumann B and Alter M, (1976) [29]	0	0
Whorl	Present study	11%	12.5%
	Study by Pawar RM and Pawar MN (2015) [30]	15%	21%
	Study by Schaumann B and Alter M, (1976) [29]	30%	22%

[Table/Fig-12]: Percentage frequency of patterns on hallucal area of the right sole among males and females.

present study and the study of Schaumann B and Alter M could possibly be considered as the reflection of the differences among different populations due to their separate genetic background as well as their separate geographical distribution. Now-a-days, digital procedures using the HP digital scanner are being utilised in some of the countries which might prove useful in procuring the prints more easily [31].

Limitation(s)

The limitation of the study was that enough data was not available in the existing review of literature to compare the findings of the present study. Another limitation was that only the right side of the prints were included in the current study. Moreover, due to poor quality of prints due to over-inking the prints had to be taken again and again.

CONCLUSION(S)

The results of this investigation suggest that there exist some significant differences between the male and female subjects of Himachali population. The plantar dermatoglyphic patterns could therefore be utilised as an important tool to determine the gender of an individual in forensic and medico-legal aspects. Moreover, the difference among different populations suggests that the dermatoglyphic patterns of the sole could be utilised to trace the relationship of an individual to an ethnic group based in different geographical areas.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Feb 28, 2023
- Manual Googling: May 02, 2023
- iThenticate Software: May 12, 2023 (14%)

ETYMOLOGY: Author Origin

EMENDATIONS: 8

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Feb 22, 2023**
Date of Peer Review: **Mar 29, 2023**
Date of Acceptance: **May 16, 2023**
Date of Publishing: **Jun 01, 2023**