ORIGINAL ARTICLE

Sexual dimorphism from toe prints among Malaysian Malays for person identification

T. Nataraja Moorthy[1], Nadiah Syarani[1], Helmi Mohd Hadi Pritam[2]*

[1]Faculty of Health and Life Sciences, Management and Science University, Shah Alam, Selangor-40100, Malaysia, [2]School of Health Sciences, Universiti Sains Malaysia, Health Campus, Kubang, Kerian, Kelantan, Malaysia

Abstract

Background: The aim of any forensic investigator is to identify the individual, both dead and alive through physical evidence found at crime scenes. Sex determination is the first step in this process that leads to identification. Foot and toe prints form a valuable clue for person for person identification. The soles of the feet are showing characteristics and a toe print is an impression of the friction ridges of toe. *Objective:* The present study was aimed to investigate the sexual dimorphism from two-dimensional (2D) toe prints among Malaysian Malays for person identification during crime scene investigation. *Material and Methods:* The study involved 200 adult Malays, a dominant ethnic group born and living in Malaysia. Out of 200 study subjects, 100 were males and 100 were females with age ranged from 18 to 60 years. By inking technique, 2D toe prints were collected and ridge density was calculated from the designated 5 mm × 5 mm square area of each toe print for all toes of all subjects. Ridge density refers to the number of friction ridge in particular demarcated areas. *Result:* The ridge density for all toes was found to be significantly higher in females than males in both sides except great toes. The correlation coefficient (r) values between fourth toe and little are found to be higher on both left (0.518) and right (0.556) sides. *Conclusion:* Ridge density shows forensic significance for sexual dimorphism among Malaysian Malays and ethnicity should be considered whenever conducting anthropological study on gender determination.

Keywords: Forensic Anthropology, Sexual Dimorphism, Toe Print, Ridge Density, Malaysian Malays

Introduction

A crime scene is a sensitive and challenging area to the investigators but is a treasure of information [1]. Human identification is mandatory step in any forensic investigation for social and legal process [2]. The crime scene may contain many physical evidence left by the perpetrators such as fingerprint [3], palm print [4], footprint [5], lip print [6], hair [7], drug [8], soil [9], nerve [10], dust [11], bloodstains [12], handwritings [13], and many others and these physical evidences are used for person identification. Footprint is an important physical evidence found mostly in murder, burg-

lary and sexual assault crime scenes. Researchers have confirmed that footprint evidence provide more information than fingerprints to the investigators [14]. The identical twins originating from one fertilized egg share the same DNA, but the footprints of twins are not sharing and distinctive [15]. In Asian countries, people in rural areas still have the habit of walking bare footed. The criminals sometimes removed their shoes or footwears to climb the walls and avoid noise during the criminal operations [16]. Researchers have shown that footprint can be used to estimate

stature [17, 18], body weight [19, 20] and gender [21]. Gender determination from footprint becomes critical requirement during crime scene investigation. Earlier researchers have estimated gender based on metric analysis of footprints [22]. The metric analysis required the footprint length is from heel end to top of all toes [23]. Based on the crime scene experience of the author (herein as TN) for more than two decades, he observed that there are many instances wherein full or complete footprints are not found in the crime scenes but only partial foot/toe prints are left by the perpetrators or victims [24]. In order to overcome this problem, researchers started ridge density study for sexual dimorphism, considering the ethnicity [25]. No researchers have conducted toe print study involving all ten toes of a person till now. Hence, the present study was aimed to investigate relating gender and two-dimensional (2D) toe prints including all toes among Malaysian Malays for person identification in forensic perspective.

Material and Methods

The study involved 200 adult Malays, a dominant ethnic group born and living in Malaysia. Out of 200 study subjects, 100 were males and 100 were females with age ranging from 18 to 60 years. Healthy subjects without any deformity or injuries in their feet were included in the study. Before sample collection, the subjects were advised to wash their feet with soap solution and wipe the moisture with cotton cloth. Following the standard procedure, the toe prints were collected by inking technique from all subjects and recorded [5-6]. The centre point in all toe prints (T1-T5) were fixed and a transparent square film with 5 mm × 5 mm square was placed on the centre point and the number of ridges (ridge density)

were counted diagonally within the square, as described by Acree [26]. Figure 1 shows the defined areas in toe prints in a Malaysian Malay subject. The number of ridges within 25mm square reflected the ridge density. The ridge density was calculated for all ten toes in both feet of a subject and recorded. The procedure was continued for all subjects and recorded the data. The data was analyzed by using Statistical Package for Social Sciences 25 and toe ridge densities were analyzed with independent t-test.
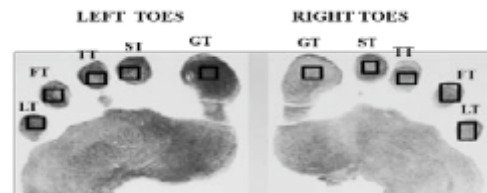
Figure 1: Illustrative example showing the defined areas in toe prints of a Malaysian Malay

Results

Table 1 presents the descriptive statistics of Ridge Density (RD) among Malaysian Malays in both sexes. The abbreviation and expansions are shown as, GT: Great Toe; ST: Second Toe; TT: Third Toe; FT: Fourth Toe; LT: Little Toe; M: Male; F: Female; RD: Ridge Density; SD: Standard Deviation. The mean RDs in the designated areas in male and female toeprints on both sides are shown in this table. The RD for all toes is found to be significantly higher in females than males on both right and left toe prints except GTs. The RD of left side toes and right-side toes are not similar and thus the RD shows bilateral asymmetry in the Malay population. In female toe prints, the mean RD on left side is comparatively higher than right side in all toes except GT.

Table 2 shows the gender difference in various toe print RDs and is found to be statistically significant in all toes. The result shows that the maximum gender difference was observed in GT, followed by FT, LT, ST and least in TT.

Table 3 presents the Pearson correlation coefficient (r) of toe print RD between the five toe prints on both sides. It is evident that RD designated areas in the five-toe prints were significantly correlated with each other. Statistically significant differences were observed in toe print RD between various toe areas in right and left sides. The correlation coefficient (r) values between FT and LT is found to be higher on both left (0.518) and right (0.556) sides.

Table 1: Ridge density statistics among gender in the Malaysian Malays

	GT		ST		TT		FT		LT	
Sample size	100 M	100 F	100 M	100 F	100 M	100 F	100 M	100 F	100 M	100 F
Right side										
Mean RD	12.47	14.58	12.73	14.18	13.75	15.02	13.53	15.27	13.15	14.88
SD	1.672	1.825	1.982	1.771	1.819	2.04	1.770	1.821	1.635	1.552
Left side										
Mean RD	12.83	14.45	12.74	14.58	13.58	15.80	13.57	16.06	13.30	15.53
SD	1.729	2.103	1.856	2.276	1.64	2.12	1.68	1.69	1.72	1.73

M: Male, F: Female, GT: Great toe, ST: Second toe, TT: Third toe, FT: Fourth toe, LT: Little toe, RD: Ridge density, SD: Standard deviation

Table 2: Sex differences in toe ridge densities of study population

	Right toe prints		Left toe prints	
	t value	p value	t value	p value
Great toe (GT)	6.624	p<0.001	8.066	p<0.001
Second toe (ST)	4.226	p<0.001	5.539	p<0.001
Third toe (TT)	3.592	p<0.001	4.600	p<0.001
Fourth toe (FT)	5.286	p<0.001	7.087	p<0.001
Little toe (LT)	4.600	p<0.001	6.404	p<0.001

Corrleation among toes	Right side		Left side	
	r	**p value**	**r**	**p value**
Great Toe – Second Toe	0.277	p=0.002	0.470	p<0.001
Great Toe – Third Toe	0.140	p=0.128	0.333	p<0.001
Great Toe – Fourth Toe	0.343	p<0.001	0.426	p<0.001
Great Toe – Little Toe	0.371	p<0.001	0.490	p<0.001
Second Toe – Little Toe	0.312	p<0.001	0.446	p<0.001
Third Toe – Little Toe	0.418	p<0.001	0.416	p<0.001
Fourth Toe – Little Toe	0.556	p<0.001	0.518	p<0.001
Second Toe – Third Toe	0.483	p<0.001	0.521	p<0.001
Second Toe – Fourth Toe	0.330	p<0.001	0.478	p<0.001
Third Toe – Fourth Toe	0.443	p<0.001	0.524	p<0.001

Table 3: Pearson correlation coefficient (r) among toe print ridge densities of study population

Discussion

Dermatoglyphic is the study of ridge pattern of the skin of fingers, palms, toes and soles. Dermal ridge differentiation takes place early in the fetal development [27]. The anatomist Bidloo provided the description of ridge details in 17th century. Researchers have conducted RD study mostly on fingerprints [28-31]. Limited studies were conducted on foot/toe print RD [21, 32-33]. But the footprint RD study was conducted mostly on sole regions with only one toe. As an experienced forensic crime scene investigator and declared footprint expert in India, the author (TN) has noticed that partial footprints / toe prints are found at many crime scenes, rather than complete footprints. The lack of footprint database and knowledge, partial footprints left by the offenders were simply neglected by the investigators in the initial stage of investigation [34]. In light of such constraints, the toe print RD can aid in narrowing down the suspects in the initial process of investigation.

Importantly, the present study analyzed all ten toe prints, unlike using only the big toe by the earlier researchers, since the presence of even a single toe print in a crime scene, would be enough to the investigators. The mean GT RD in this study shows that females have higher density value (right: 14.58, left: 14.45) than males (right: 12.47, left: 12.83). The findings in Iban population in Malaysia showed that the RD for males (right:

12.6, left: 12.9) and females (right: 13.45, left: 13.4) [14], vary from Malay population. Thus, Malay females have higher RD value than Iban females, whereas Iban males have higher RD than Malay males, reflecting the ethnic variation. Again, Indian population study in Karnataka state, India showed that the mean RD of GT for male (right: 10.40, left: 10.20) and female (right: 11.30, left: 11.20) is different from the present investigation [25]. The mean RD in GT of Iban population is higher than Indian population in both genders. Similar footprint RD study was conducted on South African population and the author had reported that the mean RD of GT was 10.6 for left side while 10.1 for right GT which are found to be smaller than Indian population [35]. Foot/Toe impressions can be in two-dimensional (2D) and three-dimensional (3D) in form, depending on the type of surfaces viz. hard or soft surfaces but RD study can be conducted on 2D impressions only [36-37]. Thus, the RD of the present population is different from Iban, Indian and South African populations. Hence the RD shows ethnic variation, the anthropological researchers are cautioned to conduct population-based study rather than mixed populations so that the findings may be explained in forensic term.

Conclusion

It is concluded that the present study provides valuable information for sexual dimorphism from toe prints among Malaysian Malay population for use in crime scene investigation. Also, the toe prints found at various crime scenes were located by the author, then CSI in India and identified the cause of death in suspicious death cases and fixed the culprits in burglary cases.

Acknowledgements

References

1. Nataraja Moorthy T. Identification of primary crime scene from secondary crime scene through soil evidence in a crime concealment case: An interesting exhumation report. *J Krishna Inst Med Sci Univ* 2020; 9(4): 98-103.

2. Nataraja Moorthy T, Ivan Nikkimor LD, Pravina D, Ariel Philip IP. Determination of stature from hand anthropometry among Visayan population in Philippine for person identification. *J Krishna Inst Med Sci Univ* 2019; 8(4): 58-65.

3. Nataraja Moorthy T, Povaneswari G. Inheritance of fingerprint pattern among Indian family members. *Int J Med Tox Legal Med* 2018; 21(3): 119-121.

4. Nataraja Moorthy T, Rajathi S. Sexual dimorphism from palmprint ridge density among Malaysian Tamils for person identification. *J Krishna Inst Med Sci Univ* 2020; 9(1): 51-57.

5. Nataraja Moorthy T, Siti Fatimah S. Individualizing characteristics of footprints in Malaysian Malays for person identification in forensic perspective. *Egypt J Foren Sci* 2015; 5:13–22.

6. Senthil Kumar B, Panner Selvi G. Sex determination by morphometry of lips. *J Krishna Inst Med Sci Univ* 2018; 7(2): 42-48.

7. Nataraja Moorthy T, Jessica Marie Roy JR. Study on hair morphology to distinguish the dominant races in Malaysia for forensic investigation. *J Foren Sci Criminol* 2015; 3(4):1-6.

8. Geetha M, Raja D, Kalaivani A. Substandard, spurious, falsely-labelled, falsified and counterfeit drugs (SSFFC): Time to take a bitter pill. *J Krishna Inst Med Sci Univ* 2016; 5(4): 122-124.

9. Nataraja MoorthyT, Hasliza H. A Comparative study of environmental subsoil profile in four different points at four different depths in Kelantan agricultural land at Kota Bharu. *Heal Environ J* 2011; 2(2): 49-56.

10. Vikram P, Chandni G, Sneha G. Morphometric study on hypoglossal and facial nerves and its significance in hypoglossal-facial nerve anastomosis. *J Krishna Inst Med Sci Univ* 2020; 9(3): 22-26.

11. Nataraja Moorthy T, Santhra Segaran B, Srinivasan M. Suspicious death – Trace evidence identified the complainant as accused. *Int J Med Tox Leg Med* 2020;23(1-2): 117-119.

12. Nataraja Moorthy T, Nadiah, Sohayla M, Attalla, Collin Babat. A challenging crime scene investigation report: Alleged murder, ravelled the mystery as lightning death. *J Krishna Inst Med Sci Univ* 2021; 10(4): 111-115.

13. Nataraja MoorthyT, Khaja Mydeen. Robber's handwritings on the wall solved the mystery: A rare case report. *J South Ind Med Leg Assoc* 2019; 11(2):119-123.

14. DiMaggio JA, Vernon W. Forensic podiatry: Principles and methods. Totowa, ON: Humana Press; 2011.

15. Winkelmann W. Use of footprints, especially bare footprint from the forensic viewpoint. *Z Rechtsmed* 1987; 99: 121-128.

16. Natarajamoorthy T, Khairulmazidah M, Mohamad Hadzri Y, Jayaprakash PT. Estimation of stature based on foot length of Malays in Malaysia. *Austra J Foren Sci* 2011; 43 (1):13-26.

17. Nataraja MoorthyT, Rasvini A. Estimation of stature from foot outline in adult Malaysian Malayalee ethnics for forensic investigation. *Sri Lanka J Foren Med Sci Law* 2016;7(2):11-20.

18. Nataraja Moorthy T, Rasvini A, Suresh Kumar S. Multiple regression analysis to estimate height from dynamic footprint anthropometry in Malaysia Indian sub-ethnic group. *Malay Appl Biol J* 2016;45(2):45-50.

19. Nataraja Moorthy T, Hairunnisa M. Determination of living body weight from foot outline length measurements among Lun Bawangs of east Malaysia. *Int J Med Tox Leg Med* 2017;1(2): 278-282.

20. Hairunnisa M, Nataraja Moorthy T, Nik FN. Body weight determination from foot outline length anthropometry among Malaysian Iban population. *Arab J Foren Sci Foren Med* 2017;1(6):656-664.

21. Nataraja Moorthy T, Hairunnisa M. Gender variation from footprint ridge density among Lun Bawangs of Malaysian Borneo for crime scene investigation. *Int J Med Tox Leg Med* 2020;23(3-4): 69-75.

22. Saka OS, Alamu OA, Olayode, Akinjisola AA, Ogundipe JO. Studies on the estimation of stature from hand and foot length of an individual. *J Krishna Inst Med Sci Univ* 2016; 5(4): 73-80.

23. Nataraja Moorthy T, Noor Hafizah H, Henky. Body weight estimation from hand anthropometry among minangs, an indigenous ethnic group in west Sumatra, Indonesia for person identification. *J Krishna Inst Med Sci Univ* 2021; 10(2): 34-42.

24. Nataraja Moorthy T, Nadiah S, Sivadurai SN, Saravanan K. Revenue Divisional Officer's inquiry on a newly-wed woman's disputed death: Toe impression indicated the cause of death - A real crime scene report. *GAP Ind J Foren Behavi Sci* 2022;3(1): 14-17.

25. Kanchan K, Krishan K, Aparna R, Shyamsunder S. Footprint ridge density: A new attribute for sexual dimorphism. *Homo* 2012;63(6): 468-480.

26. Acree MA.Is there a gender difference in fingerprint density? *Forens Sci Int* 1999; 102(1): 35-44.

27. Faulds H.On the skin – Furrows of the hand. *Nature* 1880; 22: 605.

28. Moore RT. Analysis of ridge-to-ridge distance on fingerprints. *J Foren Ident* 1989; 39(4):231-238.

29. Gungadin S.Sex determination from fingerprint ridge density. *Int J Med Update* 2007; 2(2): 1-4.

30. Jasmine KD, Anup Kumar K. Fingerprint ridge density as potential forensic anthropological tool for sex identification. *J Foren Sci* 2016; 61(2): 424-429.

31. Gnanasivam P, Vijayarajan R. Gender classification from fingerprint ridge density count and fingertip size using optimal score assignment. *Compl Intell Sys* 2019; 5:343-352.

32. Nataraja Moorthy T, Hairunnisa M, Collin Babat. Sexual dimorphism in toe impression among Bidayuhs of Malaysian Borneo for crime scene application. *J Management Sci* 2021;19(1): 62-69.

33. Nataraja Moorthy T, Hairunnisa M. Sex determination from footprint ridge density in Bidayuh population in Malaysian Borneo. *Int J Med Tox Leg Med* 2018;21(3): 158-161.

34. Nataraja Moorthy T. Neglected physical evidence during crime scene investigation. *Foren Sci Addi Res* 2017; 1(2): 1-2.

35. Laura JH, Ashion MP, Robert S. Comparison of footprint ridge density between South African ethnic groups. *J Foren Inves* 2016; 4(1): 1-4.

36. Nataraja Moorthy T, Nurul Armali Fatina M. Estimation of stature from 2D footprint measurements in Malaysian Malays by regression analysis. *Malay J Pathol* 2013; 35(2): 272.

37. Nataraja Moorthy T, Sopnashini B. Regression analysis to determine stature from foot outline (3D) anthropology among Javanese in Indonesia. *Int J Med Tox Leg Med* 2018; 21(3):101-104.

Author for Correspondence:

Prof. T. Nataraja Moorthy, Department of Forensic Sciences, Faculty of Health and Life Sciences, Management and Science University, Shah Alam, Selangor-40100, Malaysia
Email: natrajamoorthy@rediffmail.com
HP: +6 0129224610

How to cite this article:

T. Nataraja Moorthy, Syarani N, Pritam HMH. Sexual dimorphism from toe prints among Malaysian Malays for person identification. *J Krishna Inst Med Sci Univ* 2022; 11(1):77-83