A Study on Footprints of Malaysian Athletes and Non-Athletes for Application during Forensic Comparison

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ABSTRACT: The human foot has been studied for a variety of reasons, i.e., for forensic as well as non forensic purposes by anatomists, forensic scientists, anthropologists, physicians, podiatrists, and numerous other groups. Footprints are found frequently in crime scenes and form valuable evidence in forensic investigation. It is popular, especially in Asian countries, wherein bare foot walking continuous among the rural people because of their socio-economic conditions. A study on the footprints of Thai athletes and non-athletes indicated that the parameters such as footprint length, intermetatarsal distances and Flat Index were somewhat different between subjects who had experience in sports and those who did not. A study on such differences among the Malaysian sample will be of value during forensic comparison. The research reported here compared the 2D footprints between Malaysian athletes and non-athletes. The result showed the possibility of discriminating athletes from non-athletes or vice versa by comparing 2D footprints which can be applied in forensic investigation.

Key words: Forensic science, crime scene investigation, footprint, athletes and non-athletes

Introduction

Footprint is one of the valuable physical evidences left by the criminals in crime scenes [1, 2]. Offenders tend to remove their footwears to avoid noise while committing crimes and to gain better grip while climbing walls and fast escaping [3]. Useful information can be obtained from foot impression evidence. Footprints are of value in establishing the identity of the criminals in forensic investigations. Height estimation using foot measurements have been done for different populations [1, 3-11]. This impression evidence can be either 2-dimensional (2D) or 3-dimensional (3D).

A study on the footprints of Thai athletes and non-athletes has been made with the footprint parameter such as footprint length, intermetatarsal distances and Flat Index [12]. In forensic perspective, no such study has been made in Malaysia with regards to footprints of athletes and non-athletes. This pilot study in Malaysia deals with comparison of footprints between Malaysian athletes and non-athletes and to identify the footprint of athlete or non-athlete for forensic application. Using 2-D footprints, a footprint is divided into four parts viz. toes, ball area, bridge area and heel area. Usually there are five toes in a footprint designated as first toe or big toe (BT), second toe (ST), third toe (TT), fourth toe (FT) and lastly fifth toe or little toe (LT) [13]. Foot print samples collected from athletes and non-athlete in Malaysia were used during the study. The differences in footprint length parameters viz. heel to the five toes between athletes and non-athletes in Malaysia were studied.

Materials and Methods

(a) Sample collection

The study sample of subjects comprised 150 athletes and 140 non-athletes from Sekolah Sukan Bandar Penawar, and Sekolah Menengah Sains Kota Tinggi, Johor. The subjects' ages ranged from 17 to 27. A total of 580 footprints (both left and right) of 290 subjects were collected for analyses.

(b) Methodology

The feet of the subjects were washed to ensure they were free from adhesive dusts. The footprints were recorded using commercially available black fingerprint ink.

(c) Recording the footprints

The subjects were requested to step on the footprint plate, on which the footprint ink had been applied and spread evenly using the footprint roller. Care was taken to ensure the contact surface of the foot was evenly covered with black ink. Then the subjects were asked to step onto a sheet of white paper spread on an even surface, and thus a clear footprint was transferred for analysis [**Fig.1-2**]. These footprints provided the dimension of the contact surface of the plantar area of the foot, which forms the normal two-dimensional (2-D) footprint impression. Special care was taken to make sure that footprints of all the subjects were collected following the same procedure [3].

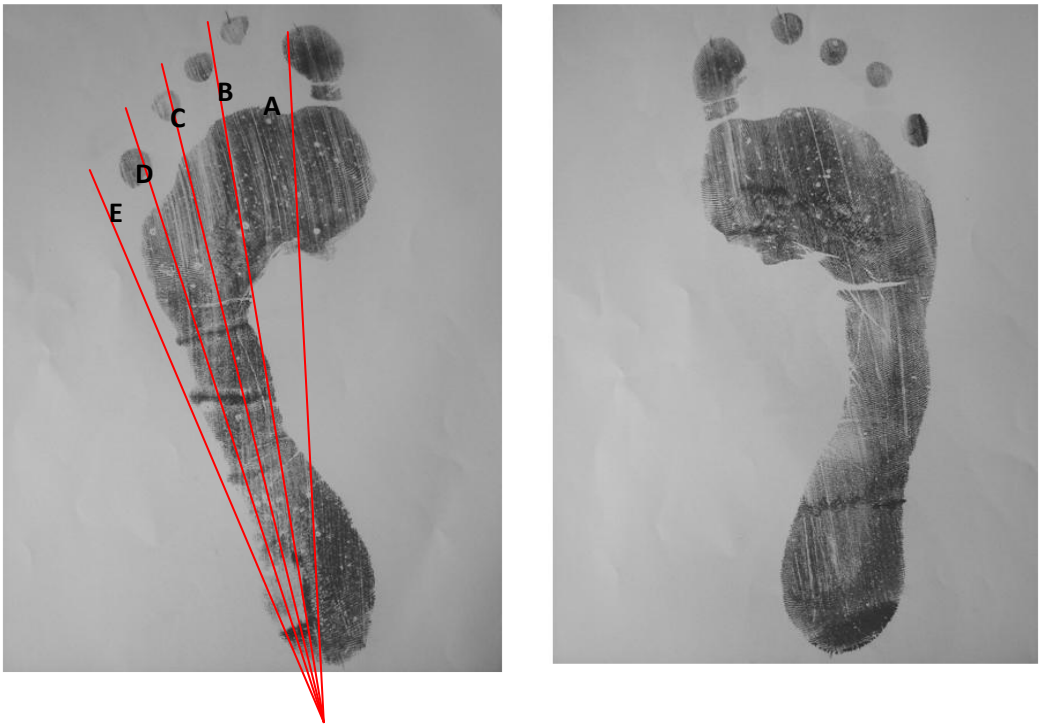

Fig 1: 2-D footprints of an athlete

Fig 2: 2-D footprints of a non-athlete

(d) Measurements

The unit for the measurement is in centimeter and recorded categorized for athletes (**Table 1**) and non-athletes (**Table 2**). The demographic data are shown in **Table 3**.

The heels to first and second toe measurements are as shown in the **Fig. 3**. The heel-toe distances as described below:

Maximum footprint length from the mid-rear heel point, pterion (pte) – to the front of first toe (big toe) is designated as (A), and

Maximum footprint length from the mid-rear heel point, pterion (pte) – to the front of second toe is designated as (B).

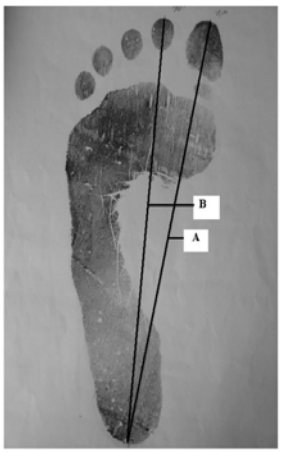

Fig 3: Heel-toes measurements [heel to first toe (A) and heel to second toe length (B)]

Table 1: The sample raw data for athlete (male and female)

Sample No [In Random]	Sex	Age	Height (cm)	Weight (kg)	Heel To Toe Length (cm)					
					Left Toe			Right Toe		
					1st	2nd	Diff 1-2	1st	2nd	Diff 1-2
1	M	15	164.5	65.0	23.0	23.9	-0.9	23.5	24.5	-1.0
2	M	17	171.0	50.0	23.5	24.5	-1.0	24.5	25.0	-0.5
3	M	17	149.0	45.0	20.5	20.0	0.5	20.5	20.5	0
4	M	15	163.8	49.0	25.0	25.5	-0.5	25.0	25.5	-0.5
5	M	16	176.9	60.0	23.0	24.5	-1.5	24.0	25.0	-1.0
6	M	15	163.5	50.0	23.5	24.5	-1.0	24.0	25.0	-1.0
7	M	17	165.2	85.0	22.5	23.0	-0.5	23.0	23.5	-0.5
8	M	16	162.5	50.0	23.0	24.0	-1.0	23.0	24.0	-1.0
9	M	17	168.5	66.0	24.0	24.5	-0.5	24.0	24.5	-0.5
10	M	17	171.5	76.0	25.0	25.2	-0.2	24.5	25.0	-0.5
11	M	16	166.9	59.0	24.5	24.7	-0.2	24.5	25.0	-0.5
12	M	16	173.0	64.5	24.5	25.5	-1.0	24.5	25.0	-0.5
13	M	16	162.8	52.0	22.0	23.0	-1.0	22.0	22.5	-0.5
14	M	17	162.0	51.3	23.5	24.0	-0.5	24.0	24.5	-0.5
15	M	25	170.0	82.0	25.0	25.4	-0.4	26.1	26.4	-0.3
16	F	20	158.0	50.0	22.2	22.5	-0.3	22.0	22.5	-0.5
17	F	21	172.0	65.0	23.2	23.7	-0.5	22.8	23.9	-1.1
18	F	20	153.0	48.0	21.5	22.5	-1.0	22.5	23.5	-1.0
19	F	21	151.0	42.0	19.8	19.9	-0.1	20.1	20.7	-0.6
20	F	19	156.5	56.0	21.9	22.4	-0.5	22.6	22.9	-0.3
21	F	19	159.0	57.0	21.1	22.0	-0.9	22.5	22.6	-0.1
22	F	19	159.0	85.0	21.1	21.5	-0.4	22.0	22.5	-0.5
23	F	19	144.5	40.0	18.6	19.5	-0.9	19.2	19.7	-0.5
24	F	20	161.0	55.0	22.3	23.0	-0.7	22.5	22.6	-0.1
25	F	20	154.0	52.0	20.5	20.8	-0.3	20.0	20.2	-0.2
26	F	19	151.0	49.0	20.6	21.0	-0.4	20.7	21.2	-0.5
27	F	17	156.7	50.0	22.0	22.1	-0.1	22.0	22.3	-0.3
28	F	17	164.7	50.0	22.0	23.0	-1.0	22.0	22.5	-0.5
29	F	17	156.5	45.0	21.5	22.0	-0.5	21.5	22.0	-0.5
30	F	17	145.0	45.0	21.0	21.3	-0.3	21.1	21.5	-0.4

Table 2: The sample raw data for non-athlete (male and female)

Sample No [In Random]	Sex	Age	Height (cm)	Weight (kg)	Heel To Toe Length (cm)					
					Left Toe			Right Toe		
					1st	2nd	Diff 1-2	1st	2nd	Diff 1-2
1	M	14	159.6	46.0	24.0	22.5	1.5	23.7	23.5	0.2
2	M	14	159.0	50.0	24.0	23.0	1.0	23.5	23.0	0.5
3	M	17	164.1	47.0	21.5	21.2	0.3	21.5	21.3	0.2
4	M	16	164.4	54.0	23.0	22.5	0.5	22.5	22.0	0.5
5	M	16	168.5	80.0	24.2	24.0	0.2	23.5	23.1	0.4
6	M	17	164.1	62.0	23.5	23.1	0.4	24.5	24.2	0.3
7	M	17	170.5	60.0	24.0	23.8	0.2	23.5	23.1	0.4
8	M	19	181.0	55.0	24.4	24.1	0.3	24.2	24.1	0.1
9	M	20	175.0	45.0	23.5	23.4	0.1	24.5	23.6	0.9
10	M	27	151.0	67.0	22.0	21.3	0.7	22.5	21.7	0.8
11	M	19	173.0	72.0	24.6	24.5	0.1	25.0	24.3	0.7
12	M	20	172.0	83.0	24.5	23.5	1.0	25.6	25.0	0.6
13	M	22	166.0	53.0	25.0	24.5	0.5	24.5	25.3	-0.8
14	M	19	163.0	57.0	25.2	24.6	0.6	25.4	25.0	0.4
15	M	21	168.0	70.0	23.9	23.5	0.4	24.1	24.0	0.1
16	F	15	157.1	56.0	21.0	20.5	0.5	21.0	20.5	0.5
17	F	17	153.6	48.0	21.5	20.5	1.0	21.5	20.5	1.0
18	F	14	153.5	59.0	21.5	20.5	1.0	21.5	21.0	0.5
19	F	14	153.7	46.0	20.5	20.3	0.2	21.0	20.5	0.5
20	F	15	149.0	59.0	22.0	21.5	0.5	21.5	21.0	0.5
21	F	15	153.9	55.0	22.0	21.5	0.5	22.5	21.0	1.5
22	F	17	153.9	70.0	21.3	21.0	0.3	21.5	20.5	1.0
23	F	14	137.5	40.0	20.6	20.0	0.6	19.5	19.0	0.5
24	F	14	150.1	49.0	20.9	20.5	0.4	20.7	20.5	0.2
25	F	14	151.4	48.0	20.7	20.5	0.2	21.0	20.5	0.5
26	F	14	149.8	52.0	20.5	20.0	0.5	20.0	19.5	0.5
27	F	14	156.8	65.0	22.5	22.0	0.5	21.5	22.0	-0.5
28	F	14	151.9	36.0	20.8	20.5	0.3	20.5	20.3	0.2
29	F	14	155.4	52.0	22.4	22.0	0.4	22.3	22.0	0.3
30	F	14	163.0	59.0	22.0	23.0	-1.0	23.5	23.0	0.5

Table 3: Demographic data of the subjects

Demographic data	Athletes (n=150)	Non-athletes (n=140)
Male	63 (42%)	50 (35.7%)
Female	87 (58%)	90 (64.3%)
Mean age (years)	17.40	17.13
Mean weight (kg)	58.56	55.85
Mean Height (cm)	160.70	159.82

Results

The raw data collected from footprint measurements of both right and left feet of the subjects were analyzed using Statistical Package for Social Science (SPSS) version 12.0.1 software.

Statistical Analysis

Mean and standard deviations were obtained for all continuous measures. The relationship between right and left foot measurements was determined by Pearson correlation coefficient. The mean difference between athletes and non-athletes was calculated by using independent t-test. The difference in frequency that the little toe or fifth toe made contact with the ground was assessed by using Chi-square test.

To investigate a specific foot (left or right) at a time, the relationships between the right and left footprint measurements were examined by using Pearson Correlation Coefficients obtained from SPSS software analysis. Here, r is regarded as a mathematical expression of the degree of association existing between paired measures. The correlation coefficient between the right and left foot is shown in the **Table 4**. All the r values have shown strong positive correlation in terms of the relationship between heels to toe lengths.

Table 4: Correlation coefficients between athletes and non-athletes

Heal-toe length	Athletes (n=150)		Non-athletes (n=140)	
	r	p-value	r	p-value
A	0.940**	< 0.001	0.944**	< 0.001
B	0.950**	< 0.001	0.945**	< 0.001

** Correlation is significant at the 0.01 level (2-tailed)

The scatter graphs were also plotted in order to check for any correlation between these variables. **Fig. 4** shows correlation between heel to toe lengths of the left footprints for athlete and non-athlete. **Fig. 5** shows the correlation between heal to toe lengths of right footprints for athlete and non-athlete**.**

The footprint study shows that for athletes, the heel to first toe length (A) is shorter than the heel to second toe length (B) for both right and left footprints irrespective of sex i.e. A – B gave negative values as shown in **Table 1**. For non-athletes, the finding is found to be opposite i.e. the heel to first toe length (A) is longer than the heel to second toe length (B) for both right and left footprints irrespective of sex i.e. A – B gave positive values as shown in Table 2.

The mean values of A and B for athletes and non-athletes for both feet are shown in **Table 4**.

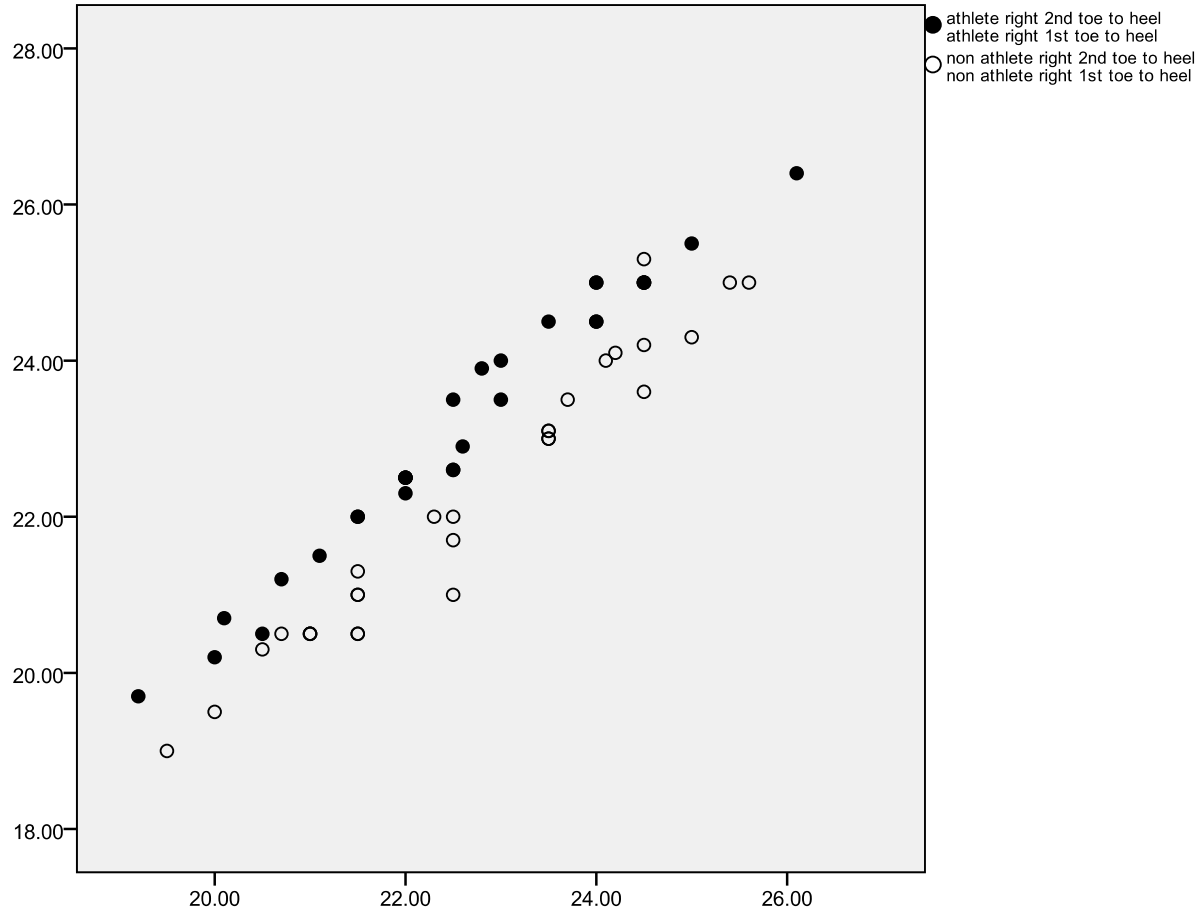

Fig. 4: Left footprint showing the relationship between heel to toe lengths for athlete and non-athlete.

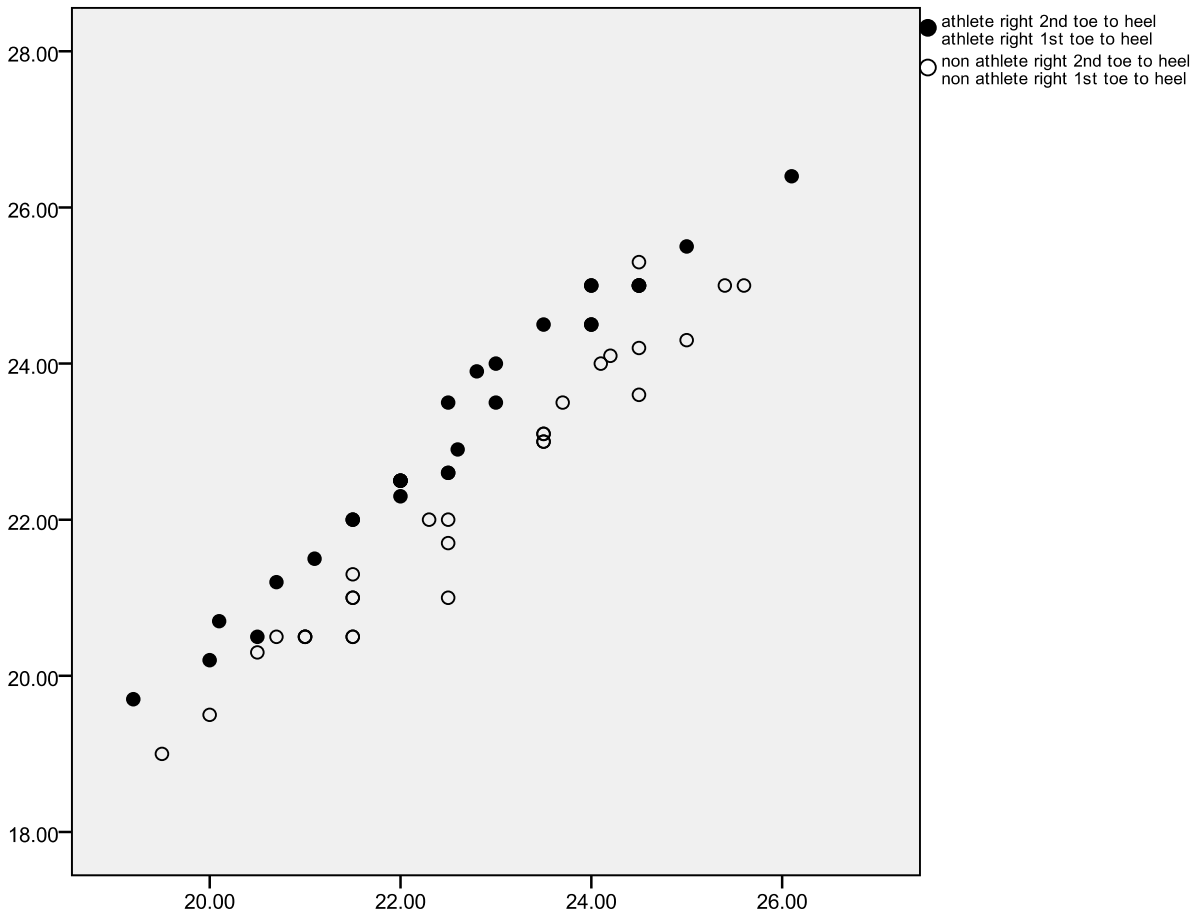

Fig. 2: Right footprint showing the relationship between heel to toe lengths for athlete and non-athlete

Table 5: Mean heel- toe length for athletes and non-athletes

Heal-toe length		Athletes (n=150)	Non-athletes (n=140)
A	Right	22.57	22.77
	Left	22.45	22.67
B	Right	23.04	22.40
	Left	22.89	22.26

Analysis of toe prints indicated some difference in fifth toe contact on the ground. The analysis was done by using the frequency analysis obtained from SPSS software analysis. The results show that the athletic group had the higher percentage of fifth toe contact on ground compared to non-athletic group, **Table 6**.

Table 6: The state of fifth toe contacting the ground

Group	The fifth toe	
	Contact	Non-contact
Male (n=113)		
Athletes	61 (96.8%)	2 (3.2%)
Non-athletes	42 (84.0%)	8 (16.0%)
Female (n=177)		
Athletes	84 (96.6%)	3 (3.4%)
Non-athletes	77 (85.6%)	13 (14.4%)

Discussion

Footprint analysis is a simple, cost-effective method to identify a person in forensic context. Study of footprint lengths between heel to first toe and heel to second toe of athletes and non-athletes indicated discrimination. The complete analyses have been done by using several suitable statistical methods obtained from SPSS analysis.

The correlation coefficients, r-values for heel to first toe length (A) and heel to second toe length (B) of 0.940 and 0.950 indicated strong positive correlation for athletic group. High correlations were also obtained for the non-athletic group wherein the values of (A) and (B) were 0.944 and B 0.945.

The mean difference calculated for both groups regarding footprint lengths heel to first toe (A) and heel to second toe (B) indicated that A is shorter than B for athletes, **Table 4**. This finding was found to be opposite to non-athletic i.e. (A) is longer than (B). This finding was consistent for both right and left footprints. The results are found to be in agreement with the study of Teerawat Kulthanan [12].

Statistical analysis indicates that higher percentage of fifth toe contacting the ground was evident for athletic group than in non-athletic group, both for males and females. The fifth toe contact on ground for male athletes was 96.8% while non-athletes was 84%. Similarly the fifth toe contact on ground for female athletes showed 96.6% while non-athletes 85.6%. This research indicated the variation in heel to 1st and 2nd toe length in 2D footprint and the extent of fifth toe contact on ground, between athletes and non-athletes which can be applied during the process of inclusion or elimination in forensic investigation.

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