A Study of Footprints in Athletes and Non-Athletic People

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Footprint analysis is a simple, cost-effective and readily available method for evaluation of flat feet, to identify a person in forensic content and for shoe manufacturing.
Objective : *To examine the footprints in athletes and non-athletes and to compare their footprint measurements.*
Material and Method : *Four hundred and ninety-two athletes and four hundred and thirty-one non-athletes were recruited. Their age range was eighteen to thirty five years. The athletes were classified by sport level : national and non-national athletes. Footprint devices, foot impression system, produced by Berkemann Company was used. The right and left foot of each subject were measured separately in a standing position. Descriptive Statistics, ANOVA, chi-square test and simple correlation were used in this study.*
Result : *The length between the heel to the first toe was shorter than that of to the second toe in national athletes. This finding was opposite to the non-athletes. The metatarsal distance in national atheletes were significantly wider than the others. The ratio of the length of footprint and body height showed significant difference between athletes and non-athletes. The Flat Index of national athletes was longer than the others. In males, the percentage of the state of contacting the ground of the fifth toe was significantly higher among athletes than non-athletes.*
Conclusion : *The footprint parameters were somewhat different between persons who had experience in sport level and general non-athletic people.*

Keyword : *Footprint analysis*

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The human foot exhibits a wide range of structural variations than in many other parts of the body. During growth, the foot changes not only its dimension but also its shape. Large variations are displayed in the normal population at different ages, specially concerning characteristics of the medial longitudinal arch.

In the past, Morley[1] studied the development of the plantar arch and found that the incidence of flat feet decreased as age increased, but his study measured only children aged one to four years. Staheli, et al[2] studied footprints obtained from normal subjects aged from one to eighty years. They similarily showed that flat feet were common in infants and children. Forriol and Pascual[3] used the Chippux-Smirak index, the ratio of the maximal width of the metatarsal region to the minimal width of the arch region of footprints, to analyze the arch type in persons aged between three and seventeen years. They concluded that the medial arch developed rapidly during the earliest years of growth.

Besides studies on arch development, foot morphologic characteristics, both low-arched (flat) feet and high-arched feet have been reported to be associated with a higher risk of injury among physically active people[4-10].

It was believed that the arch height was functionally significant for the mechanics of the foot, although no correlation has been found between arch height and performance in jumping, running, lifting and weightbearing[11]. It was clearly seen that the previous studies did not analyze footprint measurement for some groups of subjects especially athletes whose foot and toe function is essential for balance and changing body movements. Thus, this

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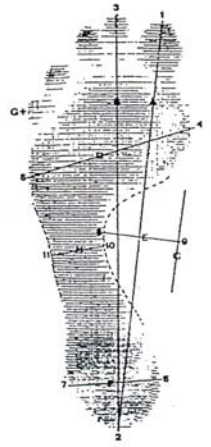
study was performed in order to obtain footprint information in athletes and to compare footprint measurements with general, non-athletic subjects. It was hypothesized that geometric indicies such as Flat Index, the length of the footprint and state of contact with the ground of the fifth toe derived from the athletes would differ from those general non-athletic subjects.

Objective

To examine the footprint parameters in Thai athletes and general non-athletic people and to compare these variables.

Material and Method

This study was conducted by the Division of Physical Education, Ministry of Education and Department of Orthopaedic Surgery, Siriraj Hospital. Both feet of 492 athletes; 314 males and 178 females and 431in the non-athlete group; 168 males and 263 females, ranging in age from 18 to 35 years old were studied. In athletes, the subjects were classified as national and non-national athletes. The interview was performed to obtain the demographic data and sport level. Each subject was weighed and his or her



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The subject stepped onto the footprint equipment, leaving a clear impression of the foot's plantar surface on the paper. When the printing was completed, the subject lifted the foot from the equipment and the procedure was repeated with the other foot. The lengths, widths of footprints were taken using a transparent ruler. The unit of mesurement was in centimeters. The footprint and its measurements are demonstrated in the figure (Fig. 1).

In taking foot-length measurements, the point of reference at different parts of the footprint were assigned including the point number 1 to 11 and G reference. The definition of the length or distance was determined as follows [12];

- distance between point No. 1 and No. 2 was the length measured from the first toe to the heel (A),
- distance between point No. 2 and No. 3 was the length measured from the second toe to the heel (B),
- distance between point No. 4 and No. 5 was the metatarsal distance (D),
- distance between point No. 4 and No. 6 was the length of the base of the longitudinal arch contour (C),
- distance between point No. 6 and No. 7 was the widest part of the heel (F),
- distance between point No. 8 and No. 9 was the width of the footprint that did not touch the ground or longitudinal arch contour (E),
- distance between No. 10 and No. 11 was the narrowest part of the footprint, point G was the markpoint that the little toe touched the ground; darkened print G means the little toe contact the ground. The Flat Index was calculated from dividing C by E (FI = C ÷ E).

Statistical analysis

Mean and standard deviations were obtained for all continuous measures. The relationship between right and left foot measurements, the distance E and body weight were determined by Pearson correlation coefficient. The mean difference between athletes and non-athletes was calculated by using one-way ANOVA. Scheffe's method was used when the mean difference show statistical significance. The difference of frequency that the little toe contacted the ground

Fig. 1 Recorded footprint, points of reference and measurements

was assessed by using Chi-square test. Significant level was at 0.05.

Results

Of the 923 subjects classified by sport level, 431 cases (46.7%) were non-athletes, 142 cases (15.4%) and 350 cases (37.9%) were national, non-national athletes respectively. The average age of the subject was 23.97 years and the age range was 18 to 35 years old. The demographic data are shown in Table 1.

The static footprint was recorded for each foot during the half body weight-bearing position. The length and width of the footprint were measured. To determine whether the separate foot should be investigated at a time, the linear relationships between the right and left footprint measurements were examined. Table 2 shows that there was significant relationships. Thus, the data for the right and left foot were pooled for further analysis and interpretation.

To investigate the difference for footprint measurements considered by sex; for male subjects, the length of the footprint (distance A) for non-athletes, national athletes and non-national athletes were 23.99 cm, 24.65 cm, and 24.11 cm respectively. There was statistical significance between the non-athlete group and national athletes (p-value < 0.001). Similarly, the metatarsal distance (distance D) in athletic subjects was higher correlated than those of non-athletes. It was found that there has no statistical significance differences for the height of the longitudinal arch (distance E) (p-value = 0.417). The Flat Index which is the ratio of the length to the height of the longitudinal arch (CE); male subjects in the non-athletic group, national and non-national athletes was 3.99, 4.34, and 3.97 respectively. There was no statistical significance differences among three groups. Similar results were observed among female subjects. The mean value, standard deviation, F-ratio and p-value of these distances are listed in Table 3.

Table 1. Demographic data of the subjects classified by sport level

	Non-athletes (n = 431)	National athletes (n = 142)	Non-national athletes (n = 350)
Sex			
Male	168 (39.0%)	97 (68.3%)	217 (62.0%)
Female	263 (61.0%)	45 (31.7%)	133 (38.0%)
Age (years)	26.08 $\pm$ 4.71	23.95 $\pm$ 3.94	21.38 $\pm$ 2.66
Weight (kg)	53.23 $\pm$ 7.91	62.94 $\pm$ 12.87	56.79 $\pm$ 7.37
Height (cm)	159.85 $\pm$ 7.66	170.90 $\pm$ 9.25	166.37 $\pm$ 7.67

Differences of footprint measurements among groups were investigated separately between male and female subjects. Similar results were observed in both sexes. The length of the footprint (distance D), and body height and length of footprint ratio were significantly different between non-athletic subjects and both national and non-national athletes are shown in Table 3. The value of each measurement was greater among athletes than the non-athletic subjects. On the other hand, the height of the longitudinal arch contour (distance E) and Flat Index (ratio of length and height of longitudinal arch contour) were not significantly different between the groups.

When comparing the length between the heel to the first toe (A) and the heel to the second toe (B) in each group, it showed that distance A was shorter than that of distance B in national athletes (distance A = 24.13 cm. distance B = 24.22 cm. p-value

Table 2. Relationship between right and left footprint measurements

Distance	Non-athletes (n = 431)		National athletes (n = 142)		Non-national athletes (n = 350)	
	r	p-value	r	p-value	r	p-value
A	0.957	< 0.001	0.965	< 0.001	0.955	< 0.001
B	0.967	< 0.001	0.971	< 0.001	0.959	< 0.001
C	0.879	< 0.001	0.882	< 0.001	0.824	< 0.001
D	0.873	< 0.001	0.899	< 0.001	0.869	< 0.001
E	0.805	< 0.001	0.686	< 0.001	0.710	< 0.001
F	0.773	< 0.001	0.780	< 0.001	0.750	< 0.001
H	0.818	< 0.001	0.834	< 0.001	0.771	< 0.001
FI	0.668	< 0.001	0.547	< 0.001	0.447	< 0.001
Height: length ratio	0.866	< 0.001	0.849	< 0.001	0.857	< 0.001

Table 3. The length of footprint measurement by sex

Distance	Non-athletes (n = 431)	National athletes (n = 142)	Non-national athletes (n = 350)	p-value
Male	n = 168	n = 97	n = 217	
A	23.99 ± 1.06	24.65 ± 1.36*	24.00 ± 1.21	< 0.001
D	9.39 ± 0.55	9.86 ± 0.66*	9.63 ± 0.55*	< 0.001
E	3.94 ± 0.87	3.87 ± 0.92	3.97 ± 0.876	0.417
FI	3.99 ± 2.09	4.34 ± 2.63	3.97 ± 2.54	0.180
Height: A	6.94 ± 0.23	7.06 ± 0.20*	7.04 ± 0.22*	< 0.001
Female	n = 263	n = 45	n = 133	
A	22.20 ± 0.91	23.01 ± 1.34*	22.48 ± 1.07*	< 0.001
D	8.55 ± 0.47	9.00 ± 0.52*	8.88 ± 0.50*	< 0.001
E	3.56 ± 0.76	3.52 ± 0.73	3.58 ± 0.79	0.808
FI	4.22 ± 3.30	4.14 ± 1.03	4.07 ± 1.72	0.766
Height: A	7.01 ± 0.22	7.14 ± 0.24*	7.16 ± 0.24*	< 0.001

* = significant between National and Non-national compared to Non-athlete group

= 0.001). The finding was opposite to those non-national athletes and the non-athletic group.

The relationship between body height and A, and body weight and E in each group among each sex was shown in Table 4. There were highly significant correlation between body height and A were observed in each group between each sex. However, only body weight and E of both male and female in non-national athletic group shows statistacally significant correlated.

Table 5 shows the state of contacting the ground of the fifth toe of each group. Study results showed statistically significant different only among three groups of male.

Table 4. The relationship between body height and A and between body weight and E

Group	Pearson correlation between			
	Body Height and A		Body weight and E	
	r	p-value	r	p-value
Male(n = 964)				
Non-athletes	0.687	< 0.001	-0.094	0.086
National athletes	0.846	< 0.001	-0.031	0.666
Non-national athletes	0.778	< 0.001	0.101	0.036*
Female(n = 882)				
Non-athletes	0.662	< 0.001	0.048	0.271
National athletes	0.821	< 0.001	0.154	0.147
Non-national athletes	0.682	< 0.001	0.152	0.013*

Table 5. The state of contacting the ground of the fifth toe

Group	The fifth toe		p-value
	contact	uncontact	
Male(n = 964)			
Non-athletes	251 (74.7%)	85 (25.3%)	
National athletes	158 (81.4%)	36 (18.6%)	0.001
Non-national athletes	372 (85.7%)	62 (14.3%)	
Female(n = 882)			
Non-athletes	382 (72.6%)	144 (27.4%)	
National athletes	67 (74.4%)	23 (25.6%)	0.465
Non-national athletes	204 (76.7%)	62 (23.3%)	

Discussion

This investigation was undertaken to determine the difference of the footprint measurements, obtained from athletes classified into national and non-national groups. compared with the non-athletic group. The study revealed that the athletes have a longer footprint length and wider metatarsal distance than those of the non-athletic group. Therefore, the foot in athletes might be bigger in foot size. The common sharing of the load between the feet would be well disposed since the wide of the support base. However, the size and shape of the foot have some hereditary basis and environmental influences such as wearing of particular types of footwear that may deform the foot.

The relationship between body height and footprint length (A) ratio was about 7:1 in athletes and slightly larger than non-athletes. This finding might be due to the nature and regularity of exercise in athletes leading them to be taller than non-athletes.

Regarding the state of contacting the ground of the fifth toe, it was formed to be of a higher percentage in athletes. It suggests that the intrinsic muscles of the foot namely the flexor digitorum brevis, the flexor halucis brevis are basically active in this group. The intrinsic muscle function would help to stabilize the arch along with the plantar aponeurosis and help in maintaining the toes flat on the ground until lift-off has occurred[13].

Conclusion

This investigation was performed to study the difference of footprint parameters between normal population and athletes. It was found that the footprint parameter such as footprint length, intermetatarsal distances and Flat Index were somewhat different between subjects who had experience in sports and those who did not.

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การศึกษารอยพิมพ์ฝ่าเท้าในนักกีฬา และบุคคลที่ไม่ใช่นักกีฬา

ธีรวัฒน์ กุลทนันทน์, สิทธิ์ เตชะกัมพุช, นที ดอนโพธิ์งาม

การวิเคราะห์รอยพิมพ์ฝ่าเท้าเป็นวิธีการที่ทำได้ง่าย และประหยัด ใช้สำหรับประเมินภาวะเท้าแบน ระบุตัวบุคคลในทางนิติเวช และใช้ในการออกแบบรองเท้าในอุตสาหกรรมผลิตรองเท้า

วัตถุประสงค์ *: เพื่อศึกษารอยพิมพ์ฝ่าเท้าในนักกีฬาและบุคคลที่ไม่ใช่นักกีฬา และทำการเปรียบเทียบค่าที่วัดได้*

วัสดุและวิธีการ *: ตัวอย่างที่นำมาศึกษา เป็นนักกีฬา 492 คน และบุคคลที่ไม่ใช่นักกีฬา 431คน มีอายุระหว่าง 18 ถึง 35 ปี กลุ่มตัวอย่างที่เป็นนักกีฬา แบ่งออกเป็น นักกีฬาทีมชาติกับนักกีฬาที่ไม่ใช่ทีมชาติ รอยพิมพ์ฝ่าเท้าวัดโดยใช้เครื่องวัดรอยพิมพ์ฝ่าเท้าจึงเป็นเครื่องวัดในแบบ Foot impression system ของบริษัท Berkemann รอยพิมพ์ฝ่าเท้า วัดทั้งเท้าขวาและซ้ายในท่ายืน สถิติที่ใช้ได้แก่ สถิติพรรณนา การวิเคราะห์ความแปรปรวน การทดสอบไคสแควร์ และสหสัมพันธ์อย่างง่าย*

ผลการศึกษา *: กลุ่มตัวอย่างที่เป็นนักกีฬา ความยาวของส้นเท้า ถึงนิ้วหัวแม่เท้าสั้นกว่าความยาวจากส้นเท้าถึงนิ้วชี้ ซึ่งพบว่าตรงกันข้ามกับบุคคลที่ไม่ใช่นักกีฬา ระยะ metatarsal distance ในนักกีฬากว้างกว่าบุคคลที่ไม่ใช่นักกีฬา อัตราส่วนระหว่างความสูงของร่างกายต่อความยาวของรอยพิมพ์ฝ่าเท้า มีความแตกต่างกันระหว่างนักกีฬากับบุคคลที่ไม่ใช่นักกีฬา Flat Index ในนักกีฬาทีมชาติมีค่ามากที่สุด การสัมผัสพื้นของนิ้วก้อย พบว่าในเพศชาย ซึ่งเป็นนักกีฬามีนิ้วก้อยสัมผัสพื้นมากกว่าบุคคลที่ไม่ใช่นักกีฬา*

สรุป *: รอยพิมพ์ฝ่าเท้าในนักกีฬามีความแตกต่างในความยาวฝ่าเท้ามิติต่าง ๆ จากบุคคลที่ไม่ใช่นักกีฬาอย่างนัยสำคัญทางสถิติ*