Rehabilitation Practice and Science

Volume 45
Issue 2 *Taiwan Journal of Physical Medicine and Rehabilitation (TJPMR)*

Article 2

12-31-2017

Plantar Pressure Distribution in Patients with Flexible Flatfoot: Measured by Platform System and In-Shoe System

Alice Chu Wen Tang

Ho Mu Wu

Chih-Kuang Chen

Simon Fuk Tan Tang

Original Article

Plantar Pressure Distribution in Patients with Flexible Flatfoot: Measured by Platform System and In-Shoe System

Alice Chu Wen Tang, Ho Mu Wu, Chih-Kuang Chen, Simon Fuk Tan Tang

Department of Physical Medicine and Rehabilitation, Linkou Chang Gung Memorial Hospital, Taoyuan

Flatfoot is characterized with insufficiency of the medial longitudinal arch and flexible flatfoot is the most predominant type which leads to numerous clinical problems. This study aimed at investigating the plantar pressure distribution in flexible flatfoot patients with platform system and in-shoe system. Nineteen flexible flatfoot patients and fifteen normal subjects were recruited. Foot Function Index (FFI) was used for subjective symptoms report, and higher scores indicated worse clinical condition. Plantar pressure were assessed with Emed-X system and Pedar in-shoe system. Student independent-t test was used for statistical analysis, and statistical significance was set at $p<0.05$. The results showed that the total score of FFI was significantly higher in flexible flatfoot patients. Emed-X system revealed that there were significantly greater contact area, peak pressure, foot maximum force and force-time integral in the medial midfoot area in flexible flatfoot patients. While Pedar in shoe system showed that there was significant decrease of peak pressure in lateral rearfoot. In conclusion, the findings of Emed-X system confirmed the crucial change of medial midfoot in flexible flatfoot patients, while the findings of Pedar in-shoe system illustrated the alteration of lateral rearfoot. These biomechanic features can be further applied in the orthosis design. (Tw J Phys Med Rehabil 2017; 45(2): 57 - 65)

Key Words: flatfoot, plantar pressure, emed, pedar in-shoe

INTRODUCTION

The foot arch is one of the major structures of the human foot, and can be divided into longitudinal and transverse arches. The bony components of the longitudinal arch include calcaneus, talus, navicular, first cuneiform, and first metatarsal bones. The transverse arch, on the other hand, include navicular, all cuneiforms, and cuboid bones. The integration of these two arches provides feet with structural elasticity while walking on various terrains, as well as shock absorption during foot impact with the ground.[1]

Flatfoot, or pes planus, leads to insufficiency of the medial longitudinal arch and is regarded as an anatomical variation in the foot structure. Epidemiological studies have shown that the prevalence rate would approximate 20% of the population.[2]According to Harris and Beath study, flatfoot could be grouped into three major types: 1. Flexible flatfoot: the range of motion (ROM) of the subtalar joint was free, and accounted for 66% of the cases. 2. Flexible flatfoot with Achilles tendon

Submitted date: 16 August 2017 Revised date: 2 January 2018 Accepted date: 17 January 2018
Correspondence to: Professor Simon Fuk Tan Tang, Department of Physical Medicine and Rehabilitation, Linkou Chang Gung Memorial Hospital and Chang Gung University, No.5 Fuxing Street, Guishan District, Tayouan, Taiwan
Tel：(03) 3281200 ext. 3846 E-mail：fttang1239@gmail.com
doi: 10.6315/2017.45(2)02

contracture: although the ROM of the subtalar joint was free, the shortened Achilles tendon could often result in several foot problems, and accounted for 25% of the cases. 3. Rigid flatfoot: restricted motion of the subtalar joint and frequently accompanied with foot pain, accounted for only approximately 9% of the cases.[2] Therefore, flexible flatfoot was the predominant foot type in flatfoot patients. Lots of clinical conditions were commonly noted in flexible flatfoot patients, including tibialis posterior tendinitis,[3] hallux valgus,[4] plantar fasciitis,[5] and metatarsalgia.[6] Understanding the different biomechanical patterns in flexible flat foot patients is crucial for successful treatment. One study applied RS-footscan 7 USB2 gait system to compare the maximal force and the arch index among adults with mild flexible flatfoot, severe flatfoot and normal foot when walking on level surfaces, upstairs and downstairs. The results showed that there were significantly greater maximal force and arch index in severe flatfoot patients compared to normal subjects.[7] The other study further investigated the effect of different insoles on plantar pressure distribution in patients with flexible flatfoot during walking. The results of Pedar-X system suggested that the peak pressure and maximum force in medial midfoot were higher in patients wearing prefabricated insole group, while the maximum force in medial midfoot was lower in patients wearing propioceptive insoles.[8] This suggested that the plantar pressure distribution was not only affected by the anatomical sturcture but also the sensory feedback.

For plantar pressure assessment, platform system and in-shoe system were both feasible yet with different characters.[9] However, most of the previous studies regarding flatfoot plantar pressure measurement were conducted with in-shoe system to adapt to different terrains and tasks.[7,8,10-13] Considering the importance of the biomechanical features in flexible flatfoot, more comprehensive study of plantar pressure distribution is essential.

This study aimed at investigating the plantar pressure distribution in flexible flatfoot patients with both platform system and in-shoe system to provide a panoramic view of biomechanical change in flexible flatfoot.

MATERIALS AND METHODS

Subjects

Flexible flatfoot was diagnosed using both clinical observation and arch index.

Patients with symptoms including pain or any discomfort on the leg or foot in the tertiary center clinics were first screened by the same physician according to following clinical observation: the medial longitudinal arch of the foot could be well observed when the patients sit on the examination table without weight bearing, but collapsed while standing.[14] Static arch index was then calculated with planimetric method which reported to have good reliability.[15] Arch indices equal or greater than 0.26 were classified as low-arched, arch indices between 0.210 and 0.260 were classified as normal foot type and arch indices lower than 0.210 were classified as high-arched according to previous studies.[15] The patients who met both the clinical and arch index criteria were recruited. Totally, nineteen patients with symptomatic flexible flatfoot and fifteen normal foot type subjects were recruited in this study.

Foot Function Index (FFI)

The Foot Function Index (FFI) is a self-administered index which consists of 23 items and is divided into 3 sub-scales including limitation, pain and disability. Visual analog scale (VAS) was used for rating of each item. The higher scores indicate the worse clinical condition. Good test-retest reliability, internal consistency and criterion validity were shown in previous studies,[16-18] and is frequently used clinically.[19] Therefore, FFI was used for subjective symptom report in this study.

Plantar pressure measurement

Emed-X system is a traditional method for collecting data using a platform system with good reliability.[18,20] The mid-gait technique requires the patient to walk across a walkway, usually at least 9M in length, while pressure data are collected from a single foot contact over the sensor platform.

The plantar pressure was also evaluated using a Pedar in-shoe pressure measurement system (Novel GmbH, Munich, Germany, Fig. 1) which also had good reliability according to previous studies.[21-23] The system consisted of the A/D conversion electronics housed in a small unit, attached to the waist of each participant. Each 99-sensor insole was connected to the A/D conversion electronics linking to a computer with a sampling rate of 50 Hz. The pressure-measuring insole had a linear response to applied loads ranging from 0 to 50 N/cm^2.

Each subject was assessed under self-selected comfortable walking velocities with shoes. There were three walking trials for each condition, and all subjects were tested bilaterally.

Data analysis

Pedar Expert software (Novel Electronics, MN, USA) was used to calculate the mean peak pressure and contact area. For analysis of plantar pressure, the insole data were divided into six regions (masks) as defined in this software. The areas included medial rearfoot, lateral rearfoot, medial midfoot, lateral midfoot, medial forefoot and lateral forefoot. The heel comprised of the first 0% to 33% of foot length, the midfoot the next 33% to 66%, and the forefoot the following 66% to 100%. The region width was divided into two equal parts (lateral and medial). At each condition, we only used entire foot contact period to analysis the peak pressure and contact areas. The most common variables of interest include peak and average pressure, force, and area. Peak pressure represents the highest pressure value recorded by each sensor over the entire stance phase. Area refers to the amount of surface contact between the plantar surface of the foot and the sensor. The area beneath the force-time curve as well as the pressure-time curve could also be determined and was referred to as the integral of the curve. The following variables were analyzed during the stance phase: contact area, peak pressure, maximum force, and the force-time integral.

Statistical analysis

The Student independent-t test was used to examine the difference in contact area, peak pressure, maximum force, and the force-time integral between patients and healthy adults. Statistical significance was set at $p<0.05$.

Figure 1. Pedar in-shoe pressure measurement system

RESULTS

Demographic Data and Foot Function Index

Table 1. revealed the demographic data of flexible flatfoot patients and control group. The mean arch index in control group was 0.232, while the mean arch index in flexible flatfoot patients was 0.264. There were more female in flexible flatfoot group and these patients were

also younger. There were no significant differences in height and weight.

Table 1. Demographic data of flexible flatfoot patients and control group

	Normal (N=15)	Flexible flatfoot (N=19)	p value
Gender (Female: Male)	7:8	14:5	0.107
Age(year)	26.1±3.3	21.9±1.6	<0.0001**
Height(cm)	169.6±10.2	163.4±9.8	0.083
Weight(kg)	68.1±18.6	61.53±13.5	0.305
Arch index	0.232±0.04	0.264±0.04	0.001**

*p<0.05; **p<0.01

Table 2. summarized the FFI score of flexible flatfoot patients and the control group. The total score of FFI was significantly higher comparing flexible flatfoot patients to the control group. And the scores of pain subscale and disability subscale were also significantly higher in flexible flatfoot patients.

Table 2. Foot Function index

	Pain	Disability	Activity limitation	Total score
Normal	1.40±2.97	0.80±1.66	0.00±0.00	2.20±4.31
Flexible flat foot	10.74±8.58**	6.84±7.88**	0.16±0.69	17.74±16.11**

*p<0.05; **p<0.01

Plantar pressure measurement-Emed-X system

Table 3. showed the contact area during stance phase measured by Emed-X system. The contact area of medial midfoot was significantly larger in flexible flatfoot patients comparing to the control group in both feet. There were no significant differences between the two groups in other foot areas.

Table 4. revealed the peak pressure during stance phase measured by Emed-X system. The peak pressure significantly increased in medial midfoot in flexible flatfoot patients in both feet comparing to the control group. And the peak pressure significantly decreased in the left lateral rearfoot comparing flexible flatfoot patients to the control group.

Table 3. Plantar pressure measurement (Emed-X system)-contact area

	L foot contact area(cm^2)		R foot contact area(cm^2)	
	Normal	Flexible flat foot	Normal	Flexible flat foot
Medial side				
Rearfoot(M1)	14.89±3.30	15.42±2.80	13.59±2.77	15.12±2.63
Midfoot(M3)	0.51±0.50	2.93±3.15**	0.40±0.50	2.76±2.58**
Forefoot(M5)	33.80±5.07	35.42±7.28	34.08±4.81	35.23±6.20
Lateral side				
Rearfoot(M2)	20.16±2.89	19.97±3.15	20.86±3.72	20.02±3.43
Midfoot(M4)	13.75±4.85	15.37±3.34	15.14±3.86	15.38±3.84
Forefoot(M6)	33.87±4.90	34.70±5.08	34.69±5.32	34.68±5.76

*p<0.05; **p<0.01

Table 4. Plantar pressure measurement (Emed-X system)-peak pressure

	L foot peak pressure(kPa)		R foot peak pressure(kPa)	
	Normal	Flexible flat foot	Normal	Flexible flat foot
Medial side				
Rearfoot(M1)	411.44±152.09	339.27±87.69	353.17±78.03	364.84±107.42
Midfoot(M3)	32.22±19.83	57.01±34.74*	24.39±22.57	56.60±28.89**
Forefoot(M5)	683.67±278.85	663.04±204.58	646.78±186.97	694.48±190.42
Lateral side				
Rearfoot(M2)	399.72±106.74	326.67±75.24*	358.17±77.27	345.49±83.58
Midfoot(M4)	100.55±48.04	104.03±34.03	118.17±47.65	104.37±44.05
Forefoot(M6)	491.06±115.60	501.37±154.77	512.33±125.13	463.18±134.84

*p<0.05; **p<0.01

Table 5. Plantar pressure measurement (Emed-X system)-foot maximum force

	L foot maximum force(N)		R foot maximum force(N)	
	Normal	Flexible flat foot	Normal	Flexible flat foot
Medial side				
Rearfoot(M1)	251.77±96.4	225.34±58.9	209.43±58.8	229.28±49.7
Midfoot(M3)	1.88±1.9	12.09±13.3**	1.55±2.0	10.96±10.6**
Forefoot(M5)	488.63±120.8	436.62±80.2	487.10±94.6	447.57±62.0
Lateral side				
Rearfoot(M2)	312.17±79.6	271.74±60.6*	317.90±91.80	276.07±62.9
Midfoot(M4)	86.51±54.2	97.08±44.2	106.30±62.20	100.20±57.2
Forefoot(M6)	349.04±114.7	352.13±117.7	371.51±126.60	327.67±154.3

*p<0.05; **p<0.01

Table 5. showed the foot maximum force during stance phase measured by Emed-X system. The maximum force significantly increased in flexible flatfoot

patients than in the control group in both feet. And the maximum force in left lateral rearfoot significantly decreased in flexible flat foot patient group comparing to the control group.

Table 6. revealed the force-time integral during stance phase measured by Emed-X system. There was significant increase of force-time integral in medial midfoot comparing flexible flatfoot patients to the control group.

Table 6. Plantar pressure measurement (Emed-X system)-force-time integral

	L foot force-time integral(Ns)		R foot force-time integral(Ns)	
	Normal	Flexible flat foot	Normal	Flexible flat foot
Medial side				
Rearfoot(M1)	53.28±21.5	49.86±19.3	44.45±15.8	48.60±15.5
Midfoot(M3)	0.28±0.3	1.96±2.1**	0.25±0.4	1.91±1.9**
Forefoot(M5)	135.05±31.4	123.70±34.8	134.22±26.8	131.49±28.0
Lateral side				
Rearfoot(M2)	70.05±21.7	60.60±16.8	70.29±25.5	61.49±18.6
Midfoot(M4)	20.68±14.7	25.00±14.8	26.58±20.2	27.02±19.7
Forefoot(M6)	116.80±26.0	110.28±41.1	125.77±34.5	110.05±44.9

*$p<0.05$; **$p<0.01$

Plantar pressure measurement-Pedar in-shoe system

Table 7. summarized the contact area during stance phase measured by Pedar in- shoe system. There were no significant differences.

Table 7. Plantar pressure measurement (Pedar in-shoe system)-contact area

	L foot contact area(cm^2)		R foot contact area(cm^2)	
	Normal	Flexible flat foot	Normal	Flexible flat foot
Medial side				
Rearfoot(M1)	19.35±1.89	18.56±2.46	18.66±1.85	19.42±1.60
Midfoot(M3)	5.15±4.46	4.64±4.71	6.36±4.18	6.94±3.79
Forefoot(M5)	37.49±4.54	36.35±5.20	39.30±4.14	38.61±4.75
Lateral side				
Rearfoot(M2)	20.26±1.51	19.89±2.40	20.76±2.57	19.62±2.67
Midfoot(M4)	15.29±2.43	14.24±3.14	15.18±2.73	14.23±3.04
Forefoot(M6)	38.47±3.65	36.59±5.08	38.94±3.61	37.85±3.33

*$p<0.05$; **$p<0.01$

Table 8. revealed the peak pressure during stance phase measured by Pedar in-shoe system. For the left foot, there were significant decrease of peak pressure in left medial rear foot and left lateral rear foot area comparing flexible flatfoot patients to the control group. For the right foot, the peak pressure significantly increased in right medial midfoot and decreased in right lateral rearfoot in flexible flatfoot patients.

Table 8. Plantar pressure measurement (Pedar in-shoe system)-peak pressure

	L foot peak pressure(kPa)		R foot peak pressure(kPa)	
	Normal	Flexible flat foot	Normal	Flexible flat foot
Medial side				
Rearfoot(M1)	273.56±65.70	224.72±32.83**	257.32±63.37	237.95±38.57
Midfoot(M3)	36.79±20.31	36.63±31.95	33.78±7.29	44.69±16.10*
Forefoot(M5)	304.52±67.81	293.59±67.49	304.00±57.95	311.42±87.27
Lateral side				
Rearfoot(M2)	260.56±43.34	220.71±31.67**	358.17±77.27	221.74±34.30*
Midfoot(M4)	77.76±23.95	73.07±17.07	118.17±47.65	77.80±23.05
Forefoot(M6)	272.63±56.52	262.53±59.66	512.33±125.13	239.42±47.80*

*$p<0.05$; **$p<0.01$

Table 9. showed the foot maximum force during stance phase measured by Pedar in-shoe system. There were no significant differences.

Table 9. Plantar pressure measurement (Pedar in-shoe system)-foot maximum force

	L foot maximum force(N)		R foot maximum force(N)	
	Normal	Flexible flat foot	Normal	Flexible flat foot
Medial side				
Rearfoot(M1)	269.89±103.89	220.92±69.85	241.57±66.82	240.46±63.71
Midfoot(M3)	12.95±12.99	15.10±16.29	14.89±11.86	19.69±11.96
Forefoot(M5)	400.25±128.34	342.27±81.11	426.73±98.53	372.09±70.62
Lateral side				
Rearfoot(M2)	237.27±40.56	225.87±60.79	243.58±59.78	209.93±64.63
Midfoot(M4)	77.54±31.06	73.45±28.38	87.31±39.17	78.72±39.18
Forefoot(M6)	348.59±91.02	302.87±97.79	351.18±88.72	309.76±102.42

*$p<0.05$; **$p<0.01$

Table 10. revealed the force-time integral during stance phase measured by Pedar in-shoe system. There were no significant differences.

Table 10. Plantar pressure measurement (Pedar in-shoe system)-force-time integral

	L foot force-time integral(Ns)		R foot force-time integral(Ns)	
	Normal	Flexible flat foot	Normal	Flexible flat foot
Medial side				
Rearfoot(M1)	80.02±37.37	60.75±25.34	72.34±26.82	65.59±21.89
Midfoot(M3)	6.49±6.59	5.40±6.98	5.49±5.58	5.77±5.62
Forefoot(M5)	123.79±41.26	104.00±36.53	133.55±38.44	117.51±31.77
Lateral side				
Rearfoot(M2)	68.74±16.90	61.89±23.71	76.96±24.15	63.87±22.82
Midfoot(M4)	27.37±12.92	25.00±15.33	30.87±17.77	27.48±19.76
Forefoot(M6)	127.33±33.49	108.91±45.41	127.46±32.64	111.64±41.30

*p<0.05; **p<0.01

DISCUSSION

The collapse of medial longitudinal arch leads to the alteration of lower limb biomechanics and might further affect the proximal part including knee, hip and lower back.[24] The results of FFI revealed that flexible flatfoot caused patients pain and further disability, which was consistent with Taspinar et al. previous study and clinical experience.[12]

Studies regarding the plantar pressure distribution in flexible flatfoot patients were relatively scarce and inconclusive. Sneyers et al. previous study assessed athletes with pressure measuring insole showed that the heel plantar load shifted anteriorly and the forefoot load decreased in flatfoot group.[11] Chuckpaiwong et al. study applied in-shoe pressure measurement to assess the effect of foot type during walking and running and showed that there were significantly greater contact area and maximum force in medial midfoot in flatfoot patients, while there were significant decrease of peak pressure and maximum forces in lateral forefoot.[10] Another Chuckpaiwong et al. study used also in- shoe pressure measurement to evaluate plantar load during four different athletics task and revealed that flatfoot patients demonstrated greater medial midfoot contact area during cross cut and side cut, and greater maximum force in medial midfoot during shuttle run and landing task.[13] In our study, we applied both platform plantar pressure measure system and in-shoe plantar pressure measure system to precisely reflect the true plantar pressure alteration. In the previous review of foot plantar pressure system, the difference of platform system and in-shoe system had been clearly elucidated.[9] Platform system is easy to operate and suitable for both static and dynamic measurement, but has the disadvantage including that only indoor measurement can be performed, and the patients have to familiarize themselves with the laboratory environment and have to do the foot contact to the center of sensing area.[9] The in- shoe system, on the other side, is suitable for various gait tasks, footwear and outdoor environment.[9] However, in-shoe system contain fewer sensors and result in lower data resolution than platform system.[9,25] Besides, many factors also affect the accuracy and precision of Pedar in-shoe system, including the quality of Pedar in-shoe system insole, calibration, and the pressure range.[26]

In our study, the results of Emed-X system revealed that the contact area, peak pressure, foot maximum force and force-time integral were all significantly increased in the medial midfoot area in flexible flatfoot patients. These findings were compatible with Chuckpaiwong et al. previous studies and also agreed with the data in many other studies.[8,10,27,28] Most important of all, the finding in our study was highly consistent, and despite the increase of contact area due to foot pronation, the significant increase of foot maximum force and force-time integral still resulted in high peak pressure in medial midfoot in flexible flatfoot patients. The results of Pedar in-shoe system showed that there were significant decrease of peak pressure in lateral rearfoot, which was in concordance with Sneyers et al. finding that heel plantar load shifted anteriorly in flat foot patients.[11]And the increase of peak pressure in right medial midfoot was consistent with the Emed-X system findings .

The findings of Emed-X system in our study confirmed the crucial change of medial midfoot in flexible flatfoot patients, and the findings of Pedar in-shoe system illustrated the alteration of lateral rearfoot. However, the change in midfoot evaluated by Pedar in-shoe system was less prominent and consistent. Whether the results of different plantar measurement systems could be used interchangeably has been discussed. One study compared the in-shoe system and platform system showed that in midfoot area, the in-shoe system recorded significantly lower average peak pressure than platform system under both unshod and shod condition.[29] While using in-shoe system, the contour footbed within the shoe might provide greater contact area and resulted in lower recorded pressure.[29] This phenomenon were also noted in our study where Pedar system recorded larger contact area in medial midfoot in both normal and flexible flatfoot patients. This reflected the fact that Pedar system might failed to detect the subtle change of midfoot kinetics due to its system limitation.

To our knowledge, this was the first study to use two plantar pressure measurement simultaneously and might further depicted the panoramic view of the biomechanics change in flexible flatfoot patients. There were several limitations in this study. First, the subjects were recruited from outpatient clinics and had symptoms such as leg or foot pain, the pain might result in fear of stepping and affect the pressure measurement. Second, the demographic data of flexible flatfoot patients and control group were not homogenous. Flexible flatfoot patients were younger and there were more female. This might be due to the fact that flexible flatfoot caused clinical symptoms in young age and female might be more willing to seek medical help..

CONCLUSION

This study applied dual plantar pressure assessments and depicted the biomechanical change in flexible flatfoot patients. Emed-X system elucidated the changes of medial midfoot in flexible flatfoot patients where greater contact area, peak pressure, foot maximum force, and force time integral were consistently noted; while Pedar in-shoe system showed that there were lower peak pressure in lateral rearfoot. In conclusion, Emed-X system illustrated the kinetics change of flatfoot patients in medial foot and the Pedar in-shoe system detected the corresponding alteration in lateral foot. Further orthosis intervention may be developed according to these biomechanics features in the future.

ACKNOWLEDGMENTS

This project was supported by Chang Gung Memorial Hospital, Taiwan R.O.C, and the grant number is CMPRG3E1743.

REFERENCE

1. Susan Standring. Ankle and Foot. In: Susan Standring, editor. Gray's Anatomy. 41st ed. Philadelphia:Elsevier; 2016. p1418-51.
2. Harris RI, Beath T. Hypermobile flat-foot with short tendo achillis. J Bone Joint Surg Am 1948;30a:116-40.
3. Herraiz Hidalgo L, Carrascoso Arranz J, Recio Rodriguez M, et al. Posterior tibial tendon dysfunction: what other structures are involved in the development of acquired adult flat foot? Radiologia 2014;56: 247-56.
4. Hagedorn TJ, Dufour AB, Riskowski JL, et al. Foot disorders, foot posture, and foot function: the Framingham foot study. PLoS One 2013;8:e74364.
5. Prichasuk S, Subhadrabandhu T. The relationship of pes planus and calcaneal spur to plantar heel pain. Clin Ortho Relat Res 1994;306:192-6.
6. Madjarevic M, Kolundzic R, Trkulja V, et al. Biomechanical analysis of functional adaptation of metatarsal bones in statically deformed feet. Int Orthop 2009;33:157-63.
7. Zhai JN, Wang J, Qiu YS. Plantar pressure differences among adults with mild flexible flatfoot, severe flexible flatfoot and normal foot when walking on level surface, walking upstairs and downstairs. J Phys Ther Sci 2017;29:641-6.
8. Aminian G, Safaeepour Z, Farhoodi M, et al. The effect of prefabricated and proprioceptive foot orthoses on plantar pressure distribution in patients with flexible flatfoot during walking.Prosthet Orthot Int 2013;37:227-32.
9. Razak AH, Zayegh A, Begg RK, et al. Foot plantar pressure measurement system: a review. Sensors (Basel) 2012;12:9884-912.
10. Chuckpaiwong B, Nunley JA, Mall NA, et al. The effect of foot type on in-shoe plantar pressure during walking and running. Gait Posture 2008;28:405-11.
11. Sneyers CJ, Lysens R, Feys H, et al. Influence of malalignment of feet on the plantar pressure pattern in running. Foot Ankle Int 1995;16:624-32.
12. Taspinar O, Kabayel DD, Ozdemir F, et al. Comparing the efficacy of exercise, internal and external shoe

modification in pes planus: A clinical and pedobarographic study. J Back Musculoskelet Rehabil 2017;30:255-63.

13. Queen RM, Mall NA, Nunley JA, et al . Differences in plantar loading between flat and normal feet during different athletic tasks. Gait Posture 2009;29:582-6.
14. Wayne Decker, Stephen Albert. Foot Pathomechanics. In: Wayne Decker, Stephen Albert, editor. Contemporary Pedorthics. 2nd ed. Seattle, Washington: Elton Wolf Publishing; 2004. p22-3
15. Cavanagh PR, Rodgers MM. The arch index: a useful measure from footprints. J Biomech 1987;20:547-51.
16. Budiman-Mak E, Conrad KJ, Roach KE. The Foot Function Index: a measure of foot pain and disability. J Clin Epidemiol 1991;44:561-70.
17. Saag KG, Saltzman CL, Brown CK, et al. The Foot Function Index for measuring rheumatoid arthritis pain: evaluating side-to-side reliability. Foot Ankle Int 1996;17:506-10.
18. Wu SH, Liang HW, Hou WH. Reliability and validity of the Taiwan Chinese version of the Foot Function Index. J Formos Med Assoc 2008;107:111-8.
19. Lau JT, Mahomed NM, Schon LC. Results of an Internet survey determining the most frequently used ankle scores by AOFAS members. Foot Ankle Int 2005;26:479-82.
20. Hafer JF, Lenhoff MW, Song J, et al. Reliability of plantar pressure platforms. Gait Posture 2013;38: 544-8.
21. Godi M, Turcato AM, Schieppati M, et al. Test-retest reliability of an insole plantar pressure system to assess gait along linear and curved trajectories. J Neuroeng Rehabil 2014;11:95.
22. Orlin MN, McPoil TG. Plantar pressure assessment. Phys Ther 2000;80:399-409.
23. Kernozek TW, LaMott EE, Dancisak MJ. Reliability of an in-shoe pressure measurement system during treadmill walking. Foot Ankle Int 1996;17:204-9.
24. Franco AH. Pes cavus and pes planus. Analyses and treatment. Phys Ther 1987;67:688-94.
25. Gefen A. Pressure-sensing devices for assessment of soft tissue loading under bony prominences: technological concepts and clinical utilization. Wounds 2007;19:350-62.
26. Hsiao H, Guan J, Weatherly M. Accuracy and precision of two in-shoe pressure measurement systems. Ergonomics 2002;45:537-55.
27. Chang H-W, Chieh H-F, Lin C-J, et al. The Relationships between Foot Arch Volumes and Dynamic Plantar Pressure during Midstance of Walking in Preschool Children. PLoS One 2014;9:e94535.
28. Imhauser CW, Siegler S, Abidi NA, et al. The effect of posterior tibialis tendon dysfunction on the plantar pressure characteristics and the kinematics of the arch and the hindfoot. Clin Biomech (Bristol, Avon) 2004; 19:161-9.
29. Chevalier TL, Hodgins H, Chockalingam N. Plantar pressure measurements using an in-shoe system and a pressure platform: a comparison. Gait Posture 2010;31: 397-9.

功能性扁平足病患之足底壓力分布：雙元足底壓力測試系統

鄧筑文　吳和穆　陳智光　鄧復旦

林口長庚紀念醫院復健科

扁平足之特點為內側縱足弓支撐性不佳，而功能性扁平足又是扁平足中盛行率最高的足型。本篇研究旨在調查扁平足患者與正常足型者於足底接觸面積(contact area)，足底最高壓力(peak pressure)，最大足底受力(foot maximum force)，以及衝力（force-time integral）等足底生物力學參數之差異。共 19 位功能性扁平足患者與 15 位正常足型者參與本研究。臨床症狀以足部功能指數(functional foot index)量化，越高分代表功能越差；而足部力學參數使用兩種足底壓力測試方法，包括平台測試系統(Emed-X system) 以及鞋內感測系統（Pedar in-shoe system）。應用 t-test 為統計方法，定義 $p<0.05$ 為有意義。結果顯示，扁平足患者具較高的足部功能指數(functional foot index)。而平台測試系統(Emed-X system)結果顯示，扁平足患者在足部中內側具較高的足底接觸面積(contact area)，足底最高壓力(peak pressure)，最大足底受力(foot maximum force)，以及衝力（force-time integral）。鞋內感測系統（Pedar in-shoe system）則顯示扁平足患者在足外後側具較低的足底最高壓力(peak pressure)。結論：平台測試系統(Emed-X system)呈現了扁平足患者在足內側的生物力學改變，而鞋內感測系統（Pedar in-shoe system）則描繪出足外側相對應的改變。此生物力學特性可進一步應用於未來的足部輔具製作。（台灣復健醫誌 2017；45(2)：57 - 65）

關鍵詞：扁平足(flatfoot)、足底壓力(plantar pressure)、足底壓力平台測試系統(emed)、鞋內感測系統(pedar in-shoe)

通訊作者：鄧復旦醫師，林口長庚醫院及長庚大學，桃園市龜山區復興街 5 號。
電話：(03) 3281200 轉 3846　　E-mail：fttang1239@gmail.com
doi: 10.6315/2017.45(2)02