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The assessment of plantar pressure distribution in plantar fasciitis and its relationship with treatment success and fascial thickness

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ABSTRACT

Aims: Patients with plantar fasciitis modify their gait patterns due to the heel pain. We aimed to investigate whether there was a significant difference in the plantar pressure distribution after pain relief due to successful treatment response in plantar fasciitis.

Methods: 49 patients diagnosed with chronic unilateral plantar fasciitis received a 3-week physical therapy intervention and home exercises. Visual analog scale, plantar pressure measurement by pedobarographic assessment and magnetic resonance imaging were performed before and 1 month after the intervention. At the 1-month follow up, participants were divided into 2 groups according to successful or poor response to treatment. The treatment's success criteria was defined as a percentage decrease in heel pain exceeding 60% compared to the baseline, assessed one month after the initiation of treatment.

Results: A total of 44 subjects successfully completed the study. In group 1, characterized by successful responders, there were 24 subjects, while group 2, comprising poor responders, included 20 subjects. After treatment in group 1, the dynamic plantar pressure on the medial forefoot showed a significant increase ($p = 0.015$). However, there was no significant change in plantar pressure in the poor responders. Plantar fascia thickness correlated positively with thumb dynamic pressures (coronal $p = 0.03$ $r = 0.434$, sagittal $r = 0.451$ $p = 0.02$).

Conclusion: The results suggest that fascial thickness and dynamic forefoot plantar pressures may be related. Medial forefoot plantar pressures increased as a result of gait restoration with significant pain reduction in adults.

Keywords: Plantar pressure, plantar fasciitis, fascial thickness

INTRODUCTION

Plantar fasciitis is the most common cause of heel pain in adults. It is a degenerative process that occurs at the plantar fascia attachment to the medial calcaneal tuberosity. The etiology of the disease is multifactorial, and many factors are thought to contribute but biomechanical dysfunction of the foot is the major contributor.[1] The diagnosis of the disease can usually be made based on history and physical examination. The definitive signs of plantar fasciitis are inferior heel pain with the first few steps in the morning or after a period of inactivity. Heel pain reduces after warm-up but worsens at the end of the day or following weight-bearing activity. Clinical assessment is sufficient for diagnosis in most cases. Although Magnetic resonance imaging (MRI) is expensive and not routinely indicated, it is a sensitive and valuable imaging method for evaluating plantar fascia morphology and provide objective data for clinical investigations.[2,3]

There are significant differences in gait kinetics and kinematics between patients with plantar fasciitis and healthy subjects. Although there is disagreement in the literature, Chang et al. concluded these compensatory differences as greater total hindfoot eversion, peak first metatarsophalangeal joint dorsiflexion, increased plantar flexion of the medial forefoot during the initial contact and reduction in propulsive ground reaction forces.[4]

Plantar pressure measurement (pedobarography) allows to measure the ground reaction forces very precisely during walking. This allows us to evaluate the plantar pressure of the foot in contact with the ground both statically and dynamically. Pedobarography serves as a valuable tool for assessing pathologies arising from compromised foot mechanics.[5] There are a few studies that investigated the plantar pressure distribution in plantar fasciitis. These patients modify their gait patterns due to heel pain. Although there are conflicting results exists in the literature, patients with plantar fasciitis make some adjustments

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such as reducing the force under the forefoot, reducing loading on the heel, and shortening the heel loading period due to reduce stretching of the plantar fascia during gait. Increased loading in another regions of the foot as midfoot can be detected due to the commissioning protective mechanisms to avoid pain.[1,6-9]

Plantar pressure assessment using pedobarography is an objective method to evaluate the ground reaction forces and foot biomechanics. Therefore, there is limited research on the effect of treatment success on plantar pressure in plantar fasciitis. The aim of the present study was to investigate how plantar pressure changes with pain reduction after treatment and the relationship with fascial thickness.

METHODS

The study was designed as a prospective clinical trial. Ethical approval was obtained from Celal Bayar University Non-Interventional Clinical Research Ethics Committee (Date: 20.06.2012, Decision No: 208, Project No: 2012-095). 49 patients diagnosed with unilateral plantar fasciitis were included in the study. Informed consent was obtained from all participants. All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. The inclusion criteria were age >18 years and a history of unilateral plantar fasciitis for at least 6 months. Diagnostic criteria included pain in the first step of the heel in the morning, worsening pain with inactivity, prolonged activity and loading, tenderness at the insertion of the proximal plantar fascia, positive windlass test negative tarsal tunnel test.[10] MRI was performed using a SIGNA_ HDXT 1.5 Tesla MRI system (GE Healthcare, Chicago, IL) before and 1 month after treatment. The maximum thickness of the proximal plantar fascia where it attaches to the calcaneus was measured using electronic calipers on fluid-sensitive MRI sequences in the sagittal and coronal planes.[11] Patients with precautions for physical therapy interventions (severe vascular disease, tumor, fracture, metal implants, use of anticoagulation agents, peripheral neuropathy and local infections), rheumatic diseases or diabetes mellitus were excluded. This study was approved by the local ethics committee with the support of the University Coordination of Scientific Research Projects.

Demographic characteristics (sex, occupation, body mass index, duration of symptoms onset) of patients were recorded. Visual analog scale (VAS) scores were used for pain during the first minutes of walking in the morning, during exercise, and during daily activities. Foot stability, arrangement, restricted activities and range of motion domains were measured using the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot scale, and plantar pressure was measured by pedobarographic assessment by a single experienced clinician. Clinical measurements, pedobarographic assessment and MRI were performed before and 1 month follow up after the intervention.

Participants were randomly assigned to receive different treatment regimens: three sessions of extracorporeal shock wave therapy (ESWT) involving 2000 shocks, 15 sessions of laser therapy (LLLT) at 8 J/cm² with a wavelength of 830 nm, or 15 sessions of continuous ultrasound therapy (US) at a frequency of 1 mHz and intensity of 2 W/cm². In addition, all participants were instructed to perform a series of home exercises, including self-mobilization and stretching of the plantar fascia, calf stretching, ankle eversion, and strengthening exercises for plantar flexion and dorsiflexion using resistance bands.[12] At the 1 month follow-up participants were divided into 2 groups according to their successful or poor response to the treatment regardless of treatment type they received. Treatmnet success criteria was defined as a reduction in heel pain of more than 60% from baseline at 1month post-treatment for at least 2 of the 3 heel pain (VAS) measures. A change of 60% has been accepted as a significant difference in previous studies[13,14] and 60% was also the median value of average VAS scores in our study.

The plantar pressures of the cases were measured using the RsScan International device (1m, 3D Scientific+Balance software model). Plantar pressure measurements were evaluated in static mode while standing and dynamic mode while walking.[15] The pressure measurement device platform includes 975x325 mm sensor area within the general framework of 1068x418x12 mm in size, containing a total of 8192 sensors, there are also 4 sensors per cm² (frequency: 500 Hz, the pressure range: 0-200 N / cm², temperature range: 15º-40º C, connection: 220/110 volt power).

A static assessment was recorded with the participant in a relaxed standing position and looking at a fixed point on the wall. The foot-to-foot distance was set at 8 cm for the static pedobarographic evaluation in our study. Peak pressures were measured from 7 plantar areas (heel medial-lateral, midfoot, forefoot medial-middle-lateral and thumb) with N/cm² metrical units and distribution of the total load percentage was recorded for forefoot and hindfoot. At least four dynamic pedobarography measurements were recorded at the participant's normal walking speed after 5 minutes of walking for practice. For dynamic evaluation, peak pressure data were recorded from seven plantar areas. Plantar contact area, and the percentage distributed to forefoot, midfoot, and rearfoot during walking which calculated by the device were noted (**Figure 1**).

Statistical Analyses

Statistical analyses were performed using the SPSS for Windows version 15.0 software. Descriptive statistics and frequency analysis were used to analyze demographic data. The Kolmogorov-Smirnov test was used to test the normal distribution of the data. The Wilcoxon Sign Rank Test was used to compare the pre-treatment and post-treatment outcomes within the group. Mann-Whitney U test was utilized to compare two groups, while McNemar test and Crosstab Chi-Square tests were used to analyze categorical data.

Pearson correlation test was used to test the correlation between continuous variables. Student's t-test was used to for pairwise comparisons in all patients. A significance level of $p<0.05$ was considered statistically significant for all tests.

RESULTS

Five out of the 49 patients missed the 1-month follow-up visit, leaving 44 participants who completed the study and were included in the analysis. The characteristics of the subjects are presented and detailed in **Table 1**.

Clinical measurements before treatments were (mean±Sd); VAS daily activities 6,79±1,17 VAS first steps in the morning 7,06±1,51 VAS exercise 7,04±1,39 , AOFAS 61,52±15,72. The number of subjects were 24 in group 1 who had successful response to the treatment, while 20 subjects in group 2 with poor response. After treatment AOFAS Ankle-Hindfoot Scale scores were measured as 90.04 ± 6.07 in group 1 (n = 24) and 75.10 ± 12.26in group 2(n = 20). There were significant differences between the two groups, in AOFAS at one month follow up p<0,001.

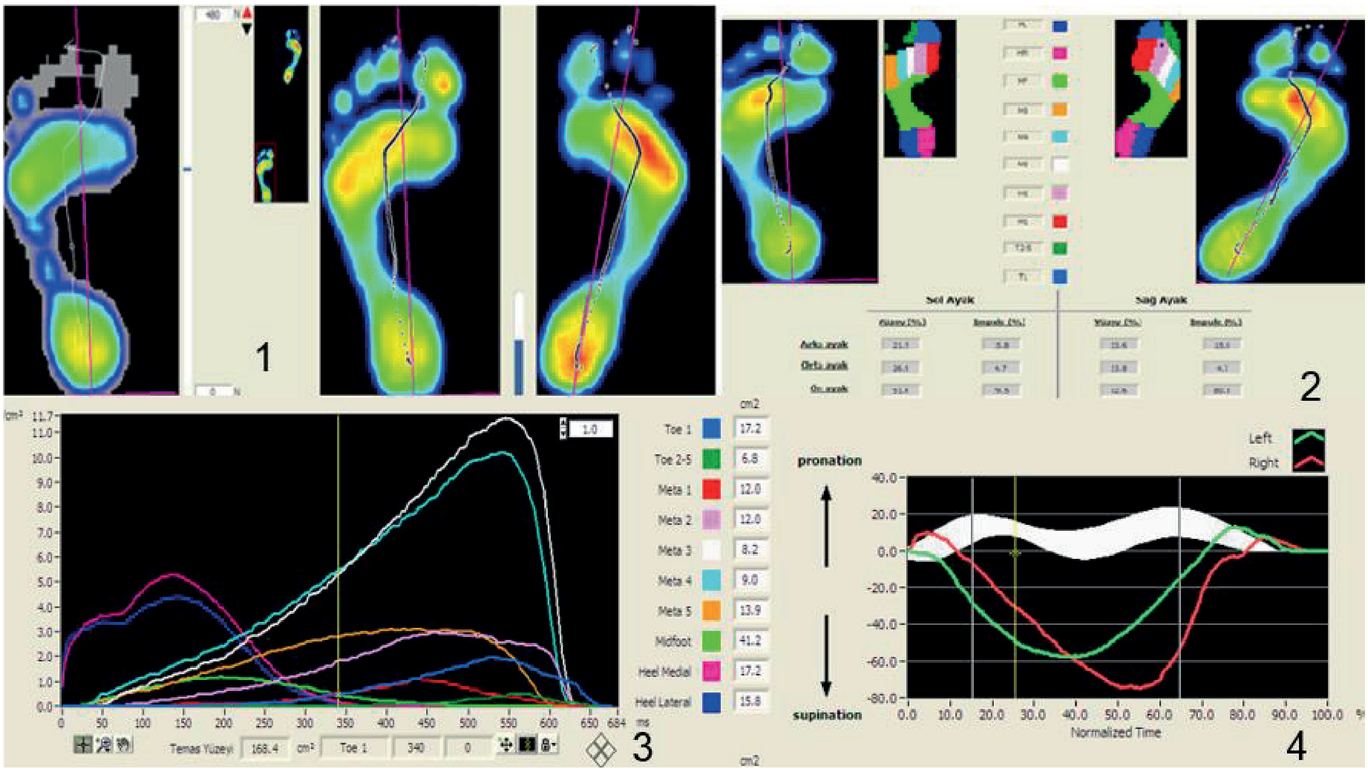


Figure 1. 1: Dynamic pedobarography evaluation,2-3: the contact area and the distribution on the foot parts, 4: evaluation of pronation and supination.

Table 1. Characteristics of the subjects		
Age	year (mean±Sd) (min-max)	53,27±9,76 (30-74)
Gender	Female n (%)	35 (%79,5)
	Male n (%)	9 (%20,5)
BMI	Kg/m² (mean±Sd) (min-max)	31,86±4,86 (22,27-41,33)
Pain Duration	Month ((mean±Sd) (min-max)	19,40±21,95 (6-120)

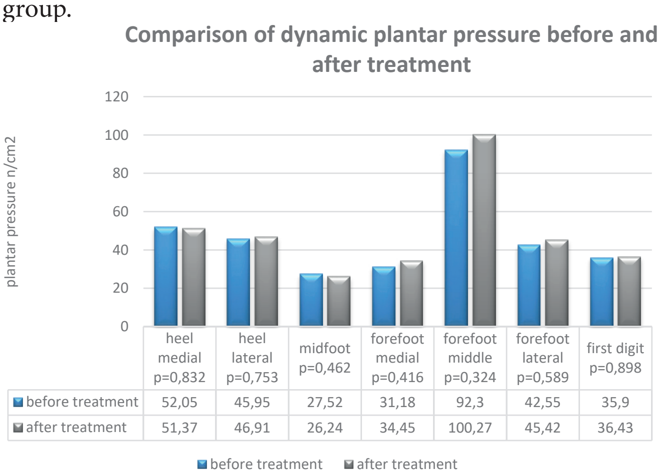
Plantar fascia thickness was measured by MRI as 4.77± 0.85 mm on the coronal plane, 4.77 ± 0,89 on the sagittal plane before the treatment. One month after the intervention, the mean plantar fascia thickness was reduced and measured 4.02 ± 0.75 mm on the coronal plane p <0.001, 4.03 ± 0.79 mm on the sagittal plane p<0,001. Both two groups showed significant improvements. There was no significant difference in fascial thickness reduction between the two groups.

When the relationship between the plantar fascia thickness and plantar pressures analyzed we detected that fascia thickness positively correlated with dynamic thumb pressure at baseline measurements (coronal p = 0.03 r = 0.434, sagittal r = 0.451 p = 0.02). There was a positive correlation between the contact area and the plantar fascia thickness (coronal p=0,008 r=0,394; sagittal p=0,006 r=0,407).

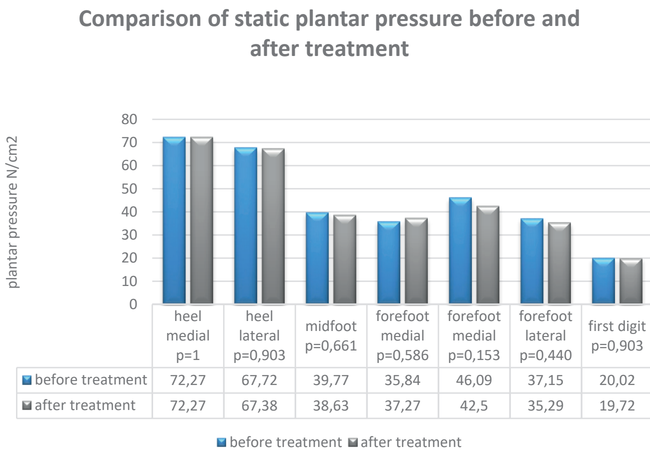
Comparison of static and dynamic plantar pressure values before and after treatment showed no significant difference in 44 subjects (Graph 1-2).

The dynamic plantar pressures of the medial forefoot were significantly increased (p = 0.015) after treatment in patients with a successful treatment response (group 1), while the static plantar pressures of the forefoot middle decreased. There was no significant change in dynamic and static plantar pressures before and after treatment in patients with poor treatment response.

When successful (n = 24) and poor (n = 20) responses groups were compared, dynamic thumb pressure significantly increased (p = 0,33) and static middle foot pressure significantly decreased (p= 0.04) in the successful response group.



Graph 1. Comparison of dynamic plantar pressure before and after treatment (n=44) there was no significant difference p>0,05 (Wilcoxon Sing rank test).



Graph 2: Comparison of static plantar pressure before and after treatment (n=44) there was no significant difference p>0,05 (Wilcoxon Sing rank test).

The contact area of the successful response group (n = 24) was significantly increased after the treatment (p = 0.049). However, there was no statistically significant difference in the contact area and percentage distribution of the area in the poor response group (n = 20) p> 0.05.

DISCUSSION

In this study, we aimed to evaluate the changes in plantar pressures in patients diagnosed with plantar fasciitis before and after treatment. The results showed that within the group of successful responders, medial forefoot plantar pressures increased due to the restoration of gait and a significant reduction in pain. This study is particularly valuable as it contributes to the limited body of research on non-athlete plantar fasciitis patients, providing insights into the pathology of biomechanics and treatment guidance through pedobarographic measurements.

In the literature, there have been varying results concerning plantar pressure distribution in patients with heel pain. Sullivan et.al. reported a decrease in peak posterior lateral heel plantar pressure in patients with heel pain, a decrease in maximum heel force and a lower decrease in peak anterior medial heel plantar pressure of patients with sharp heel pain when compared to patients with slight heel pain.[8] However, Riberio et.al. have compared 60 healthy subjects with 45 runners diagnosed with plantar fasciitis and found no difference in plantar pressure distribution.[9] Katoh et.al.didn't determined any differences in the hindfoot; they found that the impulses decrease in the forefoot and increase in the midfoot.[16] Bedi and Love, on the other hand, argued for an increase in forefoot, a decrease in midfoot pressure with no effect on the hindfoot.[17]

Lunen et al. found a reduction in pain in patients with plantar fasciitis who received orthotics or bandages, but they didn't find significant differences in peak plantar pressures after treatment.[18] Hsu et.al. identified an improvement in the VAS scores in patients they treated with ESWT as well as an increase in peak forefoot pressures.[6] In our study, we found an increase in the dynamic plantar pressure values of the forefoot medial within the successful responders group. Similar to the findings of Hsu et al, these results can be explained by the attainment of a normal gait pattern due to the restoration of the foot after pain relief.

Additionally, when comparing patients who successfully responded to treatment to who did not, the dynamic thumb pressure was significantly increased in patients who had a successful response to treatment. The plantar fascia affects the dynamic of the foot mostly when the foot is moving, and the Windlass mechanism also supports this mechanism. We also detected a decrease in the static middle forefoot pressure after treatment in the successful group.

Regarding the effects of increased local loading on structural factors and plantar fascia thickness; Giacomozzi et.al. found a correlation between plantar fascia thickness and vertical forces beneath the forefoot during walking in patients with diabetic neuropathy.[19] Similarly, there is a presence of fascial thickening in plantar fasciitis and plantar pressure distribution is affected in patients but this relationship between fascial thickening and forefoot plantar loading could only be defined in diabetic patients.[20] Wearing et al.[7] have shown that there is a positive correlation between fascia thickness and middle foot loading in plantar fasciitis We also identified a positive correlation between fascia thickening and dynamic thumb pressure in patients with plantar fasciitis. The decrease in the plantar fascia flexibility due to fascia thickening and increase in toe pressure is the reason behind this. In addition, we found a positive correlation between fascia thickness and total contact area, which may be related to a decrease in arch height due to the increasing tensile forces resulting from fascia thickening.

This study has several limitations, including the relatively small number of patients and the lack of a control group. The study was conducted using one month of data, the absence of a more extended observation period represents another constraint of our study.

CONCLUSION

Our results suggest an association between fascia thickness and dynamic forefoot plantar pressures in patients with plantar fasciitis. The observed increase in medial forefoot plantar pressures is likely a result of gait restoration after a significant pain reduction. This study contributes to the understanding of plantar fasciitis and its treatment implications, but further research with larger sample sizes and control groups is necessary to validate and extend these findings.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was obtained from Celal Bayar University Non-Interventional Clinical Researches Ethics Committee (Date: 20.06.2012, Decision No: 208, Project No: 2012-095).

Informed Consent: All patients signed and free and informed consent form.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Wearing SC, Smeathers JE, Urry SR. The effect of plantar fasciitis on vertical foot-ground reaction force. *Clin Orthop Relat Res*. 2003;(409):175-185.
2. Lawrence DA, Rolen MF, Morshed KA, Moukaddam H. MRI of heel pain. *AJR Am J Roentgenol*. 2013;200(4):845-855.
3. Draghi F, Gitto S, Bortolotto C, Draghi AG, Ori Belometti G. Imaging of plantar fascia disorders: findings on plain radiography, ultrasound and magnetic resonance imaging. *Insights Imaging*. 2017;8(1):69-78.
4. Chang R, Rodrigues PA, Van Emmerik RE, Hamill J. Multi-segment foot kinematics and ground reaction forces during gait of individuals with plantar fasciitis. *J Biomech*. 2014;47(11):2571-2577.
5. Kanarlı U, Yetkin H, Songür M, Ozturk A, Bolukbasi S. Yürüme analizinin ortopedik uygulamaları. *TOTBID J*, 2006;5(1-2):53-59
6. Hsu WH, Lai LJ, Chang HY, Hsu RW. Effect of shockwave therapy on plantar fasciopathy. A biomechanical prospective. *Bone Joint J*. 2013;95-B(8):1088-1093.
7. Wearing SC, Smeathers JE, Sullivan PM, Yates B, Urry SR, Dubois P. Plantar fasciitis: are pain and fascial thickness associated with arch shape and loading?. *Phys Ther*. 2007;87(8):1002-1008.
8. Sullivan J, Burns J, Adams R, Pappas E, Crosbie J. Plantar heel pain and foot loading during normal walking. *Gait Posture*. 2015;41(2):688-693.
9. Ribeiro AP, Trombini-Souza F, Tessutti VD, Lima FR, João SM, Sacco IC. The effects of plantar fasciitis and pain on plantar pressure distribution of recreational runners. *Clin Biomech (Bristol, Avon)*. 2011;26(2):194-199.

10. Martin RL, Davenport TE, Reischl SF, et al. Heel pain-plantar fasciitis: revision 2014. *J Orthop Sports Phys Ther*. 2014;44(11):A1-A33.
11. Lawrence DA, Rolen MF, Morshed KA, Moukaddam H. MRI of heel pain. *Am J Roentgen*. 2013;200(4):845-855.
12. Ulusoy A, Cerrahoglu L, Orguc S. Magnetic resonance imaging and clinical outcomes of laser therapy, ultrasound therapy, and extracorporeal shock wave therapy for treatment of plantar fasciitis: a randomized controlled trial. *J Foot Ankle Surg*. 2017;56(4):762-767.
13. Gerdesmeyer L, Frey C, Vester J, et al. Radial extracorporeal shock wave therapy is safe and effective in the treatment of chronic recalcitrant plantar fasciitis: results of a confirmatory randomized placebo-controlled multicenter study. *Am J Sports Med*. 2008;36(11):2100-2109.
14. Gollwitzer H, Diehl P, von Korff A, Rahlfs VW, Gerdesmeyer L. Extracorporeal shock wave therapy for chronic painful heel syndrome: a prospective, double blind, randomized trial assessing the efficacy of a new electromagnetic shock wave device. *J Foot Ankle Surg*. 2007;46(5):348-357.
15. Cerrahoglu L, Koşan U, Sirin TC, Ulusoy A. Range of motion and plantar pressure evaluation for the effects of self-care foot exercises on diabetic patients with and without neuropathy. *J Am Podia Med Assoc*. 2016;*106*(3):189-200.
16. Katoh Y, Chao EY, Morrey BF, Laughman RK. Objective technique for evaluating painful heel syndrome and its treatment. *Foot Ankle*. 1983;3(4):227-237.
17. Bedi HS, Love BR. Differences in impulse distribution in patients with plantar fasciitis. *Foot Ankle Int*. 1998;19(3):153-156.
18. Van Lunen B, Cortes N, Andrus T, Walker M, Pasquale M, Onate J. Immediate effects of a heel-pain orthosis and an augmented low-dye taping on plantar pressures and pain in subjects with plantar fasciitis. *Clin J Sport Med*. 2011;21(6):474-479.
19. Giacomozzi C, D'Ambrogi E, Uccioli L, Macellari V. Does the thickening of Achilles tendon and plantar fascia contribute to the alteration of diabetic foot loading? *Clin Biomech (Bristol, Avon)*. 2005;20(5):532-539.
20. D'Ambrogi E, Giurato L, D'Agostino MA, et al. Contribution of plantar fascia to the increased forefoot pressures in diabetic patients. *Diabetes Care*. 2003;26(5):1525-1529.