Original Article

Plantar Pressure Distribution Among Diabetes and Healthy Participants: A Cross-sectional Study

Abstract

Background: Plantar Pressure distribution refers to the distribution of force over the sole of the foot. Recently many studies indicate plantar pressure distribution assisted in determining and managing the impairment related to musculoskeletal disorders. **Methods:** This cross-sectional study was conducted with forty participants (20 diabetes type 2 patients +20 healthy) from Imam Abdulrahman bin Faisal University. All the measurements were taken in the morning session. To measure height and weight, participants took off their shoes and stood on the stadiometer. The body mass index determined with the help of a bioelectric impedance device to get the health level of the participants—Proclaimed diabetes type 2 patients selected for the data collection. Tekscan's Mobile Mat was used to determine the plantar pressure of healthy and diabetes participants. **Results:** The finding revealed that diabetes participants have more pressure in the mid-foot section, whereas healthy participants showed more pressure on the heel section. The metatarsal section showed similar types of pressure distribution in both participants. The result also revealed that diabetes participants have more peak pressures, time integral, and gradient than healthy participants. Significant differences between diabetes and healthy participants were existing. **Conclusions:** The findings highlight the importance of measuring plantar pressure distribution since these are known to incorporate in the main parts of the foot and thus provide a shred of constructive evidence for the total load exposer of a single leg static task.

Keywords: *Diabetes, healthy subject, peak pressure, plantar pressure, pressure time integral volunteers*

Mohammad Ahsan, Alsayed A. Shanab, Shibili Nuhmani

Department of Physical Therapy, College of Applied Medical Sciences, Imam Abdulrahman Bin Faisal University, Dammam, Kingdom of Saudi Arabia

Introduction

The foot is an overly complicated multi-segmented structure and plays a significant role in all daily living activities. Postural stability could be achieved due to the appropriate physiological pressure distribution pattern of foot. Pressure distribution has been assisted in determining and managing the impairments related to many musculoskeletal disorders. An abnormal pattern of plantar pressure distribution in patients with diabetes caused poor stability that has developed over time to many foot complications.

Earlier investigations have been done to examine the differences and association in plantar pressure in normal foot, low and high arch type of foot during walking or running, with many deformities or injuries, and on diverse types of population. A relationship has been shown between multi-segmented foot structure and foot function concerning plantar pressure measurements.[1] In patients with diabetes, evaluation of plantar pressure is essential for the prevention of foot complications, due to higher mechanical stress along with loss of plantar protective sensation. It is believed the most significant factors in skin breakdown, developing in diabetic foot ulceration.[2] An earlier study suggested that patients with diabetes for more than ten years may have increased peak plantar pressure.[3] Increased pressures believed to raise the risk of ulceration in patients with diabetes, particularly when combined with deformity and peripheral neuropathy.[4] The hindfoot, midfoot, metatarsal heads, and big toe are the most common sites prone to deformities as well as ulcers.[5] A similar finding reported in a study that determines 57 percent substantial risk for ulceration at high-pressure points. The distinct areas of the foot, such as heel, midfoot, metatarsal heads, and hallux, were positively related to peak plantar pressure and the occurrence of foot ulcers.[6] Patients with diabetes for a history of ulceration were compared to healthy individuals and found that patients

How to cite this article: Ahsan M, Shanab AA, Nuhmani S. Plantar pressure distribution among diabetes and healthy participants: A cross-sectional study. Int J Prev Med 2021;12:88.

Address for correspondence:
Dr. Mohammad Ahsan, Assistant Professor, Department of Physical Therapy, College of Applied Medical Sciences, Imam Abdulrahman Bin Faisal University, Dammam 31451, Kingdom of Saudi Arabia.
E-mail: mahsan@iau.edu.sa

Access this article online
Website: www.ijpvmjournal.net/www.ijpm.ir
DOI: 10.4103/ijpvm.IJPVM_257_20
Quick Response Code:

with diabetes have higher plantar pressure on the lateral side of the forefoot area.[7] Patients with diabetes carry up to 25 percent lifetime risk of foot ulceration, whereas healthy people were ranging from 4 to 10 percent.[8]

Plantar pressure measurement frequently used to assess various static and dynamic conditions associated with many health conditions, illnesses, and disabilities. Apart from all these conditions, plantar pressure distribution might cause by the age, height, weight, health, and fitness of the individuals.[9] Distinguishes techniques implemented, and various dependent variables elected to determine foot condition. The plantar pressure distribution determined through pressure platform or in-sole systems, and elected variables were the peak pressure or pressure-time integral. Earlier findings existed investigating the differences in plantar pressure distribution during walking, running, as well as dynamic movements. Therefore, the present research aimed to evaluate the differences in plantar pressure distribution at the static position between patients with diabetes and healthy participants.

Methods

Study design and setting

This cross-sectional study was conducted at the physical therapy department, IAU Dammam. For data collection, 40 male (20 diabetes type-2 patients + 20 healthy) participants were chosen without condition affecting their ability to stand on a single (dominant) leg.

Sample size calculation

The sample size determined by using http://www.stat.ubc.ca/~rollin/stats/ssize/n2a.html which used plantar pressure 2nd region of right foot (N/cm^2) mean ($\mu1$ = 17.58, $\mu2$ = 12.51) and standard deviation (5.32) of a previous study (Ozturk, B., Angın, E., GUchan, Z., Yurt, Y. and Malkoc, M. (2016) Assessment of the Plantar Pressure. The significant value was 0.05 and power 80.

Participant's characteristics

The selection criteria for participants were the patients with diabetes had diabetes histories for more than five years. The healthy participants were those BMI exist in between 18.5 and 24.9. None of the participants had previous foot ulceration, neuropathy, or any type of dysfunction involving the foot. Table 1 showed that anthropometric measurements and arch height index are insignificant at 0.05 level of significance in between patients with diabetes and healthy participants. It is also evident that the data are normally distributed.

Table 1: Anthropometric characteristics of patients with diabetes and healthy participants

	Diabetes		Healthy		*t*
	Mean	SD	Mean	SD	
Age (Yr)	47.23	1.28	38.44	4.75	-0.47
Height (cm.)	171.57	5.47	173.45	5.38	-0.46
Weight (kg.)	83.37	2.44	76.85	6.49	-1.08
BMI (kg/m^2)	28.81	4.85	21.57	3.52	-1.00
Arch Height Index	0.24	0.04	0.25	0.05	-0.47
Glucose (mmol/L)	8.7	2.8	5.8	0.8	-0.46

Tools

Stadiometer

Stadiometer (Detecto 8430S Scale–USA) was used to measure the standing height; it is established the gold standard.

Body composition analyzer

Bioelectrical impedance device (ioi-353, Jawon Medical, S.Koria) was used to determine the health status of participants. The manufacturer's instructions followed to measure body composition.

Blood glucose monitor

A blood glucose kit (OMRON HGM-111) was used to measure the level of blood glucose in the body through strips. These strips allow the device to detect the level of glucose as per the drop of blood.

Takscan's MobileMat

The MobileMat 3140 is Tekscan's standard resolution portable pressure mat. It was used to determine static plantar pressure. Tekscan's MobileMat equipped with innovative software that was used for a variety of applications to capture and evaluate static and dynamic trails.

Statistical analysis

Data were statistically analyzed using SPSS (version 24.0). Descriptive and inferential statistics calculated. An independent sample t-test was applied for statistical analysis to compare between two groups. Statistical significance was determined at P value <0.05, and confidence interval at 95%.

Procedure

Ethical clearance was obtained from the deanship of research. Informed consent was taken from all participants. A verbal explanation also imparted regarding the test procedure before the actual test. All measurements were made in the morning session—height and weight measured by using a stadiometer. Body mass index determined with the help of a bioelectrical impedance device to get the health level of the participants—Proclaimed diabetes type-2 patients selected for data collection. The glucose level at the time of the test determined with a blood glucose device. A trained physical therapist used a lancing device to get a drop of blood from the fingertip. Blood was dropped on the edge of the test strip, and blood glucose levels appeared on the device's display—the plantar pressure measured by Tekscan's MobilMat. Participants stand barefoot on a single leg (dominant) upon the MobileMat device for forty seconds without any movement. The data were recorded in software and later extracted for statistical analysis

Results

On comparing the different pressure distribution to different sections of the foot in between patients with diabetes and healthy participants, it was found that there were no significant differences between patients with diabetes and healthy participants for the metatarsal and midfoot segment. It is evidence from the Table 2 that *'t'* values for midfoot and metatarsal are -1.02 and -0.38 respectively was non-significant at. 05 level of significance. Whereas, pressure for the heel section was significant, with' t' value -0.02 in between patients with diabetes and healthy participants.

On comparing the plantar pressure parameters in between patients with diabetes and healthy participants, it was found that there were insignificant differences between patients with diabetes and healthy participants. It is evident from Table 3 that the *"t"* value, that is, -0.47, -0.46, -1.08, and -1.00 for PP, PSI, PTI, and PPG respectively, was not significant at the 0.05 level of significance. Hence, there was no significant difference between the plantar pressure parameters of patients with diabetes and healthy participants.

On comparing groups and within groups for patients with diabetes and healthy participants for plantar pressure distribution, it was found that there is a significant difference both between groups. It is evident from Table 4 that the 'F' value is 41.43 and 132.94 for patients with diabetes and healthy participants respectively and significant between-group at the 0.05 level of significance.

Table 2: Comparisons of pressure distribution at different sections of the foot in between patients with diabetes and healthy participants

	Patients with diabetes		Healthy participants		*t*
	Mean	SD	Mean	SD	
Pressure distribution at different sections (kPa)					
Heel	552.85	249.02	551.25	215.40	-0.02
Mid-foot	602.10	231.92	527.75	226.97	-1.02
Metatarsal	482.55	235.42	455.10	217.71	-0.38

Table 3: Comparisons of plantar pressure (kPa) parameters between patients with diabetes and healthy participants

	Patients with diabetes		Healthy participants		*t*
	Mean	SD	Mean	SD	
Pressure					
PP	588.15	192.38	564.15	125.65	-0.47
PSI	449.10	213.19	417.25	221.19	-0.46
PTI	474.80	177.47	423.60	116.95	-1.08
PPG	57.40	12.51	52.15	19.91	-1.00

PP (Plantar Pressure), PSI (Pressure per Square inch), PTI (Pressure Time Integral), and PPG (Peak Pressure Gradient)

Table 4: Comparison between groups and within groups for patients with diabetes and healthy participants for plantar pressure distribution

	Sum of Squares	Mean Square	*F*	Sig.
Patients with diabetes				
Between Groups	10761430.03	1076143.003	41.43	0.000
Within Groups	5429208.48	25977.074		
Healthy participants				
Between Groups	412659.22	41265.922	132.94	0.000
Within Groups	64876.97	310.416		

Discussion

In this study, an attempt has been made to assess the static plantar pressure distribution to compare patients with diabetes and healthy participants. The results showed that patients with diabetes have more mean body mass and BMI than healthy participants. It is suggested from data that higher BMI and body mass cause higher plantar pressure and pressure distribution at different foot sections in patients with diabetes. Sutkowska *et al*. found that the most elevated pressure on the lateral part of the foot and midfoot has been noticed in patients with a BMI ≥35.[10] It is identified that high body mass, abnormal plantar pressure, and pressure distribution are associated with many foot disorders like Achilles tendinitis and pea plants.[11] Additionally, elevated body mass and abnormal plantar pressure and pressure distributions might be factors for damage muscle and pathological changes in medial longitudinal arch height.[12] Morag and Cavanagh studied the plantar pressure and foot structure, and the study indicated that elevated peak pressure under the first metatarsal head with low arch height.[13] The finding of a study showed that participants with high foot arch lean to carry load sideways and experience more pressure distribution on the lateral side of the forefoot and relatively less in the mid-foot area.[14] The reason for such indifference may be attributed to the high incidence of hammer-toe deformity, which associated with patients with diabetes and the main cause for high plantar pressures. Foot deformities and arch height also cofounding causes of high plantar pressure distribution patterns in patients with diabetes.[15] Findings showed that patients with diabetes have a lower arch height index when compare to healthy participants. It is very recognized that the lower height of the medial longitudinal arch can cause an expansion in the contact force and foot contact area.[16] Due to this reason, it is more likely that elevated plantar pressure, contact area, PSI, and PTI cause medial longitudinal arch height.

The study examined differences in plantar pressure distribution patterns at different sections and found that the mean of static pressure distribution was slightly higher in patients with diabetes than healthy participants. These results are also consistent with Basnet *et al*. revealed that static peak plantar pressure in patients with diabetes is elevated than healthy participants.[17] Tatiana AB *et al*. studied plantar pressure distribution patterns in patients with diabetes and found that patients with diabetes with and without neuropathy revealed higher plantar pressure than control participants.[18] Zimny *et al*. also reported that midfoot and forefoot have higher peak pressure and peak time integral in a group of adults with diabetes.[19] Caravaggi *et al*. also give emphasize that plantar pressure distribution over the forefoot is associated with types of diabetes and the course and severity of diseases.[20] Searle A. *et al*. conducted a study on foot plantar pressure for 136 adult male patients with diabetes and found that elevated pressure-time integral was significantly associated with adult patients with diabetes.[21] Robinson *et al*. also revealed that peak plantar pressure higher in prediabetes and patients with diabetes than healthy control participants.[22] The finding of the study also revealed that patients with diabetes have more pressure in the mid-foot section, whereas healthy participants showed more pressure at the heel section. The metatarsal section showed similar types of pressure distribution in both type participants.

The study revealed a significant difference does not exist for PP, PSI, PTI, and PPG while comparing the plantar pressure parameters. The result from our study is consistent with those earlier investigations, which demonstrated that an increase in the mean pressures in both feet while compared to the control group.[23] Although not statistically significant elevated mean plantar pressures have been reported as a consistent finding in patients with diabetes.[24] Result emphasized the importance of measuring PSI, PTI, PPG since this is known to incorporate all pressure parameters in different particular areas of foot and thus provide a value for the total load exposure of that specific area while standing. Since it has been informed that aggregate exposure of pressure and time can start foot impairment, PTI could be considered as an essential contributory factor in determining foot complication.[25] Liu *et al*. investigated differences between diabetic and healthy subjects and reported that significant variations existed, and the mean pressure of patients was 2.5% than healthy subjects.[24] A study revealed that patients with diabetes shown peak pressure, and pressure-time integral significantly is higher when compared with healthy subjects.[21] The finding of our research also revealed that patients with diabetes have higher plantar pressures, time integral, and gradient as compared with healthy participants. The mean differences between patients with diabetes and healthy participants showed a statistically significant difference.

Limitation

It should be observed that this study has certain restrictions. The participants were selected based on the convenience sample and not equaled and balanced, which could be affected by group differences. These potential preferences were at least partly avoided through the application of quotients for our significant outcome variables on pressure distribution at different sections and plantar pressures parameters.

Conclusions

Our findings highlight the importance of measuring PP, PSI, PTI, PPG since these are known to incorporate in the main parts of the foot and thus provides a shred of constructive evidence for the total load exposer of a single leg static task.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Received: 13 May 20 **Accepted:** 27 Jul 20
Published: 09 Jul 21

References

1. Cavanagh PR, Morag E, Boultom AJM, Young MJ, Deffne KT, Pammer SE. The relationship of static structure to dynamic foot function. J Biomech 1997;30:243-50.
2. Zou D, Mueller MJ, Lott DJ. Effect of peak pressure and pressure gradient on subsurface shear stresses in the neuropathic foot. J Biomech 2007;40:883-90.
3. Anjos DM, Gomes LP, Sampaio LM, Correa JC, Oliveira CS. Assessment of plantar pressure and balance in patients with diabetes. Arch Med Sci 2010;6:43-8.
4. Barn R, Waaijman R, Nollet F, Woodburn J, Bus SA. Predictors of barefoot plantar pressure during walking in patients with diabetes, peripheral neuropathy and a history of ulceration. PLoS One 2015;10:e0117443.
5. Nouman M, Leelasamran W, Chatpun S. Chatpun. Effectiveness of total contact orthosis for plantar pressure redistribution in neuropathic diabetic patients during different walking activities. Foot Ankle Int 2017;38:901-8.
6. Ledoux WR, Shofer JB, Cowley MS, Ahroni JH, Cohen V, Boyko EJ. Diabetic foot ulcer incidence in relation to plantar pressure magnitude and measurement location. J Diabetes Complicat 2013;27:621-6.
7. Singh N, Armstrong DG, Lipsky BA. Preventing foot ulcers in patients with diabetes. JAMA 2005;293:217-28.
8. Lavery LA, Armstrong DG, Wunderlich RP, Tredwell J, Boulton AJ. Predictive value of foot pressure assessment as part of a population-based diabetes disease management program. Diabetes Care 2003;26:1069-73.
9. Zulkifli SS, Loh WP. A state-of-the-art review of foot pressure. Foot Ankle Surg 2020;26:25-32. Https://doi.org/10.1016/j.fas.

2018.12.005.

10. Sutkowska E, Sutkowski K, Sokołowski M, Franek E, Dragan S. Distribution of the highest plantar pressure regions in patients with diabetes and its association with peripheral neuropathy, gender, age, and BMI: One centre study. J Diabetes Res 2019;2019:7395769.
11. Dufour AB, Losina E, Menz HB, LaValley MP, Hannan MT. Obesity, foot pain and foot disorders in older men and women. Obes Res Clin Pract 2017;11:445-53.
12. Tas S, Bek N, Ruhi Onur M, Korkusuz F. Effects of body mass index on mechanical properties of the Plantar Fascia and heel pad in asymptomatic participants, Foot Ankle Int 2017;38:779-84.
13. Morag E, Cavanagh PR. Structural and functional predictors of regional peak pressures under the foot during walking. J Biomech 1999;32:359-70.
14. Teyhen DS, Stoltenberg BE, Collinsworth KM, Giesel CL, Williams DG, Kardouni CH, *et al*. Dynamic plantar pressure parameters associated with static arch height index during gait. Clin Biomech (Bristol, Avon) 2009;24:391-6.
15. Buldt AK, Forghany S, Landorf KB, Levinger P, Murley GS, Menz HB. Foot posture is associated with plantar pressure during gait: A comparison of normal, planus and cavus feet. Gait Posture 2018;62:235-40.
16. Basnet S, Maiya A. Comparison of static plantar pressure in patients with diabetes and healthy individuals. J Sci Med Sport 2017;15:S361.
17. Bacarin TA, Sacco IC, Hennig EM. Plantar pressure distribution patterns during gait in diabetic neuropathy patients with a history of foot ulcers. Clinics 2009;64:113-20.
18. Zimny S, Schatz H, Pfohl M. The role of limited joint mobility in diabetic patients with an at-risk foot. Diabetes Care 2004;27:942-6.
19. Caravaggi P, Berti L, Leardini A, Lullini G, Marchesini G, Baccolini L, *et al*. Biomechanical and functional alterations in the diabetic foot: Differences between type I and type II diabetes. Gait Posture 2017;57(Suppl 3):12-3.
20. Searlea A, Spinka MJ, Chutera VH. Prevalence of ankle equinus and correlation with foot plantar pressures in people with diabetes; Clin Biomech 2018;60:39-44.
21. Robinson CC, Balbinot LF, Silva MF, Achaval M, Zaro MA. Plantar pressure distribution patterns of individuals with prediabetes in comparison with healthy individuals and individuals with diabetes. J Diabetes Sci Technol 2013;7:1113-21.
22. Gravante G, Pomara F, Russo G, Amato G, Cappello F, Ridola C. Plantar pressure distribution analysis in normal weight young women and men with normal and claw feet: A cross-sectional study. Clin Anat 2005;18:245-50.
23. Borg J, Mizzi S, Formosa C. Peak pressure data and pressure-time integral in the contralateral limb in patients with diabetes and a trans-tibial prosthesis. Gait Posture 2018;64:55-8.
24. Liu R, Hu M, Gu Y, Lin H, XU B, XU J Zhou J. Differences in plantar pressure between the diabetic and healthy subjects. Leather Foorware J 2017;17:193-8.
25. His WL, Chai HM, Ali JS. Comparision of pressure and time parameters in evaluating diabetic footwear. Am J Phys Med Rehabil 2002;81:822-9.