Patterns of Planter Pressure Distribution among Diabetic Subjects with and without Peripheral Neuropathy (Comparative Study)

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ABSTRACT

Purpose: This study was conducted to compare the patterns of planter pressure distribution in diabetic subjects with and without peripheral neuropathy. **Subjects:** sixty diabetic subjects were included in the study. Their age ranged from 45 to 67 years old with a mean value of 55.33 ±3.84 year. Thirty subjects were complicated with peripheral neuropathy (group I). The other thirty subjects were not complicated with peripheral neuropathy (group II) **Procedure**: Six parameters were evaluated in the foot during the static and dynamic phases: Peak plantar pressure under the big toe (PPPT1), Peak plantar pressure under lesser toes (PPPLT), Peak plantar pressure under the first metatarsal head (PPPMT1), Peak plantar pressure under lesser metatarsal heads (PPPMT), Peak plantar pressure under the mid foot (PPPMT) and Peak plantar pressure under heel value (PPPH). **Results**: There was significant difference in the mean values of peak plantar pressures at (PPPT1), (PPPMT1) and (PPPLMT) in both static and dynamic measurements. **Conclusions**: There were changes in patterns of planter pressure distribution in patients with diabetic neuropathic feet, in which there were higher PPPT1, PPPMT1 and PPPLMT when compared to a group of diabetic patient without peripheral neuropathy.

***Key words*:** planter pressure, diabetes mellitus, diabetic neuropathy.

INTRODUCTION

Diabetes mellitus is a complex metabolic disorder characterized by persistent hyperglycemia resulting from deficits in insulin secretion that lead to disorder of carbohydrates, fat and protein metabolism, it affects 15% of world population over the age of 65 years in developed countries. The rate of incidence of diabetes reaches a percentage of 20-50% throughout different age group [1].

The incidence of type II diabetes increases with age, as the most cases being diagnosed after age of 40 years and it is highly associated with family history of diabetes, obesity, lack of exercise. Type II diabetes is characterized by insulin resistance in peripheral tissue and hyperinsulinemia [2].

Neuropathy is a general term for physical damage or impairment of the human nervous system. It has many causes and wide symptoms. Because a long period of time with elevated blood glucose can damage nerve fibers, diabetes is one of several major causes of neuropathy [3].

Diabetic peripheral neuropathy (DPN) is a polyneuropathy because of the diffuse damage to all peripheral nerve fibers,

motor, sensory and autonomic. Such damage occurs insidiously, progressively and characterized first by sensory loss and later by loss of motor function, in a stocking and glove distribution [4].

The research literature has reported the existence of a strong association between diabetic neuropathy and higher plantar loads that may be responsible for foot ulceration and re-ulceration [5].However, some authors have not found elevated peak pressures for all ulcerated patients [6].

Most of skin injuries in neuropathy-type diabetic foot patients occur on the planter soft tissue at the sites of abnormally high pressure values that could lead to skin breakdown and ulceration. If not detected and treated early enough, these localized sites are likely to put the patient at higher risks including the need for amputation [7].

Neuropathy in the lower extremity and increased foot pressure are associated with the development of diabetic foot ulcers. Examination of these factors is crucial to enhance understanding of diabetic foot ulcers pathology and enable to design effective preventive interventions [8].

The assessment of plantar pressure is used independently in either laboratory or clinical setting to help direct treatment options, and for patient education. When the values of plantar pressure are determined to be atypical, the information can be used to modify a patient management program through alteration in footwear, foot orthoses, exercise programs and alteration of weight bearing. Information obtained from pressure systems is also useful from a research perspective to address many questions regarding the relationships between plantar pressure and lower extremity posture [9].

The purpose of this study was to compare the changes in the patterns of planter pressure distribution in diabetic patients with and without peripheral neuropathy, which will help the practitioner to avoid more serious complications by starting early and effective preventive interventions.

METHODOLOGY:

Subjects:

This observational analytic study was conducted in the diabetic foot lab at the Rehabilitation Department of Zagazig University Hospital. Sixty subjects diagnosed as having type 2 diabetes since at least 10 years were included in this study. Their age ranged from, 45 to 67 years old with a mean value of 55.33 ±3.84 years. Thirty subjects were complicated with diabetic peripheral neuropathy (DPN) since at least one year, have been selected to represent group (I). The other thirty subjects were not complicated with peripheral neuropathy and represented group (II). Fasting blood glucose level for those patients was measured within 24 hours before participation of study, and had to be below 160 mg/dl. All patients were referred from diabetic out patient's clinic of Zagazig University Hospital.

Exclusion criteria

Patients with the following clinical disorders were excluded from participating in this study

1. Diabetic foot ulcers
2. Uncontrolled blood glucose level
3. Muscloskeletal problems as deformities of the spine, extremities or the feet

Assessment tools

Pressure distribution measurement platform model FMD-S manufacture in zebras medical GmbH, serial number 170242, made in Germany, number of sensors 1536, resolution 1sensor/cm^2 , measuring platform for analyzing the static and dynamic pressure distribution

Assessment procedure

Assessment of static plantar pressure distribution.

The platform model FDM-S analyzed the static pressure distribution in real-time either two or three dimensional. The measurement takes about 20 seconds

The subject stood barefoot in upright position on the platform with his feet separated slightly (fig 1) in which the right and left foot defined by the device, then the measurement started, It is stopped automatically after the selected measurement duration. During static measurements the subjects were asked questions to prevent concentration to the foot and to prevent the wrong tended posture from causing over pressure on one side of the foot. They were asked to look at a constant point on the wall during the measurement. The pressure values were analyzed separately for both the right and left foot. [9].

The following six parameters were evaluated in the foot during the static standing position measurement: Peak plantar pressure under the big toe(PPPT1), Peak plantar pressure under lesser toes(PPPLT), Peak plantar pressure under the first metatarsal head(PPPMT1), Peak plantar pressure under lesser metatarsal heads(PPPLMT), Peak plantar pressure under the mid foot(PPPMT) and Peak plantar pressure under heel (PPPH) .

Fig. 1 Assessment of static plantar pressure

Assessment of dynamic planter pressure distribution

The patient walked two steps over the platform. There should be only one roll-off sequence on the plate, the device measurement starts with the first ground contact and ends automatically after a certain time.

The same six parameters were evaluated in the foot during walking over the platform dynamic activity (PPPT1, PPPLT, PPPMT1, PPPLMT, PPPMF, and PPPH).

STATISTICAL ANALYSIS

The statistical analysis was performed with Statistical Package for Social Sciences (SPSS).version 20.

The data were analyzed by calculating: Mean ± Standard deviation.

Unpaired t test was used to compare the mean planter pressure between both groups, considering a significance level at P= 0.05.

RESULTS

Table 1. Anthropometric measurements of both groups

Variable	**Group I n=30**	**Group II n=30**	***P-value***	***sig***
Age (years)	54.33±3.84	56.23 ±3.45	0.15	NS
Weight(Kg)	84.2 ± 10.5	79.8 ± 10.7	0.11	NS
Height(Cm)	168.7±11.3	165.6 ± 10.6	0.21	NS
BMI(Kg/m^2)	29.8 ± 3.2	28.2 ± 3.4	0.068	NS

Results in Mean ± Standard Deviation, NS: non-significant

Table 2. Planter pressure distribution under the left foot in static and dynamic phases in both groups.

Variable	Group I n=30	Group II n=30	P- value
PPPT1(N/cm^2)			
Static	4.9 ± 1.77	3.86 ± 1.98	0.037*
Dynamic	36.7 ± 12.6	29.2 ± 14.9	0.039*
PPPLT(N/cm^2)			
Static	3.5 ± 2.87	3.7 ± 2.4	0.26
Dynamic	10.77 ± 4.89	10 ± 5.1	0.55
PPPMT1 (N/cm^2)			
Static	5.3 ± 1.67	4.1 ± 1.9	0.011*
Dynamic	22.3 ± 7.8	18 ± 7.02	0.03*
PPPLMT (N/cm^2)			
Static	7.1 ± 3.3	4.9 ± 1.7	0.002*
Dynamic	26.87 ± 8.1	21.8 ± 7.1	0.012*
PPPMF (N/cm^2)			
Static	4.76 ± 1.57	4.2 ± 1.37	0.14
Dynamic	14.93 ± 6.1	15.5 ± 6.5	0.69
PPPH(N/cm^2)			
Static	9.6 ± 2.76	10.5 ± 6.72	0.121
Dynamic	20.1 ± 6.5	21.7 ± 7.2	0.063

Results in Mean ± Standard Deviation *: p < 0. 05

PPPT1: Peak plantar pressure under the big toe, PPPLT: Peak plantar pressure under lesser toes, PPPMT1: Peak plantar pressure under the first metatarsal head, PPPLMT: Peak plantar pressure under lesser metatarsal heads, PPPMT: Peak plantar pressure under the mid foot and PPPH: Peak plantar pressure under heel.

Table 3. Planter pressure distribution under the right foot in static and dynamic phases in both groups.

Variable	Group I n=30	Group II n=30	P-value
PPPT1(N/cm^2) Static Dynamic	5.3 ± 3.4 40.6±17.8	3.63±1.67 25.5±12.1	0.018* 0.021*
PPPLT(N/cm^2) Static Dynamic	4 ± 3.95 8.7 ± 4.36	3.4 ± 2.1 8 ± 5.9	0.06 0.62
PPPMT1($N/cm^{2)}$ Static Dynamic	5.3± 2.64 21.5±7.82	4.07±1.36 17.2±6.97	0.02* 0.028*
PPPLMT(N/cm^2) Static Dynamic	6 ± 3.3 26.1±7.46	4.3 ± 1.27 22.18±7.91	0.01* 0.04*
PPPMF (N/cm^2) Static Dynamic	5.5 ± 2.4 17.5 ± 8	5.17±2.37 17.3±6.67	0.59 0.91
PPPH (N/cm^2) Static Dynamic	8.5 ± 3.2 19.76±6.2	9.1 ± 3.4 20.8 ± 6.2	0.063 0.056

Results in Mean ± Standard Deviation

*: $p < 0.05$

PPPT1: Peak plantar pressure under the big toe, PPPLT: Peak plantar pressure under lesser toes, PPPMT1: Peak plantar pressure under the first metatarsal head, PPPLMT: Peak plantar pressure under lesser metatarsal heads, PPPMT: Peak plantar pressure under the mid foot and PPPH: Peak plantar pressure under heel .

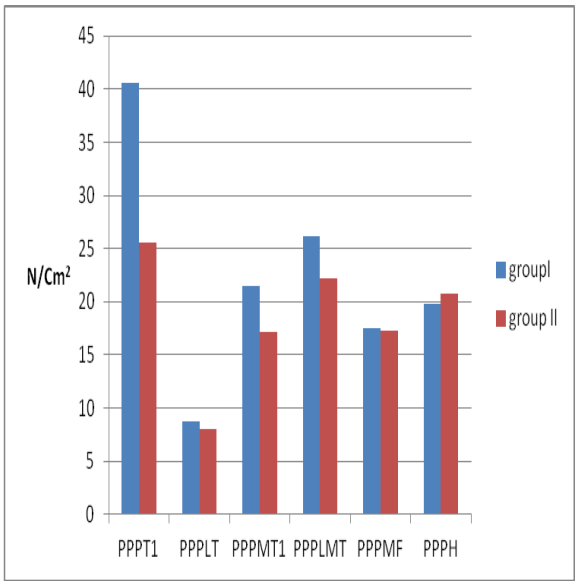

Fig. 2 planter pressure distribution under the left foot in static phase in both groups.

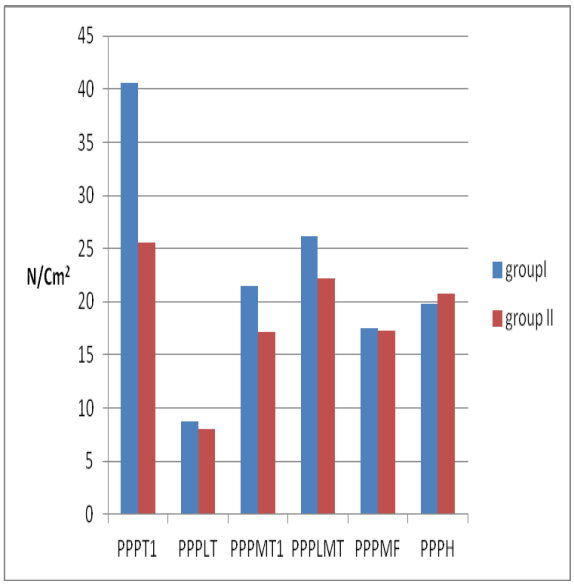

Fig. 3 planter pressure distribution under the right foot in dynamic phase in both groups.

DISCUSSION

Many studies confirmed a high plantar pressure as a principal factor in the development and non-healing of plantar ulcers in diabetic patients[5, 6, 10].

The results of the current study revealed that there were significant differences in the mean values of peak plantar pressures under the big toe (PPPT1), first metatarsal head(PPPMT1) and the lesser metatarsal heads (PPPLMT) in both static and dynamic measurements for both right and left feet.

The results of this study were supported by the work of Pataky et al. [11]) who studied the distribution of plantar pressure during walking in 15 patients with type 2 diabetes mellitus and compare them with 15 non-diabetic control subjects. They found that a significant increase in peak plantar pressure distribution at the level of big toe and at 5th metatarsal head. They concluded that plantar pressure elevation, together with the prolonged duration of the foot –floor contact time, even in the absence of sensory loss, may be an early sign of neuropathy

The mechanisms by which the peripheral diabetic neuropathy causes plantar pressure elevation are well described. One relates to altered proprioception with an imbalance between the long flexors and extensors of the toes, which in its advanced form give rise to the claw toes and prominent metatarsal heads. Clawing of the toes is accompanied by anterior displacement of submetatarsal head fat pads. These structure changes lead to increase supinatory moments in neuropathic feet with an increased pressure under 4th and 5th metatarsal heads. Such changes in plantar pressure may occur before clinically evident peripheral neuropathy [12].

The cumulative plantar tissue stress was estimated in subjects with diabetic peripheral neuropathy with a history of recurrent ulcers. It was shown that these patients had lower daily cumulative plantar tissue stress as compared to neuropathic subjects who had never developed a foot ulcer. Authors have suggested that after an initial episode of skin breakdown, plantar tissue may become more susceptible to future lesions as a result of disuse atrophy following treatment of the first episode, so that plantar tissues re-ulcerate even under low stress [13].

It has been shown that neuropathic groups, both non-ulcerated and ulcerated, presented alterations in plantar pressure distribution patterns, and the ulcerated patients presented higher loads than non-ulcerated [14].

It has been revealed that Neuropathic subjects with no history of foot ulcers represent patients at an earlier stage of neuropathy than those with a history of foot ulcers. Considering this fact, neuropathy itself first alters plantar pressure distribution, then the ulcers occur, and after healing, the dynamic pattern remains altered and worsens plantar load distribution, predisposing patients to re-ulceration[5, 6, 15].

On the other hand, it has been reported reduced toe–loading in early diabetic neuropathy [16].However the results were based on a global assessment of the whole area under all toes. Our results were based on foot pressure evaluation under the hallux and lesser toe. The absence of plantar pressure evaluation under other toes could explain the differences in result. Moreover, the pervious study included both type 1 and type 2 diabetic subjects, while the present study included patients with type 2 diabetes.

The results of current study showed that, there were no significant (P>0.05) differences in the mean value of peak plantar pressure at the mid foot, lesser toes and heels in both static and dynamic phases for both right and left feet.

These results come in agreement with Mueller et al. [17] who determined differences in stress variable peak plantar pressure (PPP) between the forefoot and the rear foot in twenty-four subjects, they found that the peak planter pressure (PPP) was greater in the forefoot compared with the rear foot.

It has been revealed that the forefoot may experience higher stress values than the rear foot which attributed to the increased soft tissue thickness in the rear foot than in the forefoot. Soft tissue clearly plays an important role in stress distribution, and the thicker tissue under the rear foot compared with the forefoot may help to distribute stresses evenly to the underlying bony structures[18].

Furthermore, it has been mentioned that the most common sites for diabetic ulcers is under the metatarsal heads. As diabetic neuropathic patients seem to have a deficiency of the eccentric contracting capacity in their tibialis anterior muscle, which would lead to forefoot slap and increases the planter pressure under the metatarsal heads[19].

CONCLUSION

From the results of the current study we concluded that there were changes in the patterns of planter pressure distribution in patients with diabetic neuropathic feet, in which there were higher PPPT1, PPPMT1 and PPPLMT when compared to a group of diabetic patient without peripheral neuropathy. Plantar pressure distribution assessment is important for physical therapist to design more appropriate treatment plans in such patients as well as more strategies to prevent diabetes mellitus complication.

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الملخص العربي

انماط توزيع الضغط الاخمصى فى مرضى السكرى مع او بدون اعتلال الاعصاب الطرفى (دراسة مقارنة)

تهدف هذه الدراسة الى مقارنة انماط توزيع الضغط الاخمصى فى مرضى السكرى مع اوبدون اعتلال الاعصاب الطرفية. وقد تم اختيار ستون مريضا من مرضى السكرى تم تقسيمهم الى مجموعتن : المجموعة الاولى وتكونت من 30 مريض يعانون من السكرى مع اعتلال الاعصاب الطرفية، والمجموعة الثانية وتكونت من 30 مريض يعانون من السكرى بدون اعتلال الاعصاب الطرفية. وقد تم قياس الضغط الاخمصى لجميع المرضى فى حالتى السكون والحركة فى ستة نقاط مختلفة. واوضحت النتائج اختلاف ذو دلالة معنوية بين المجموعتين وارتفاع الضغط الاخمصى فى المجموعة الاولى فى ثلاثة نقاط: تحت الاصبع الاول، تحت عظمة مشط القدم الاولى وتحت عظمة مشط القدم الاخيرة. ويستخلص من هذه الدراسة وجود تغيرات فى انماط توزيع الضغط الاخمصى فى مرضى السكرى المصابين باعتلال الاعصاب الطرفية عندمقارنتهم بمرضى السكرى الغير مصابين باعتلال الاعصاب الطرفية.