Pedobarography in Diagnosis and Clinical Application

Amira Skopljak1,2, Mirsad Muftić2,3, Aziz Sukalo4, Izet Masic1
Cathedra for Family medicine, Faculty of Medicine, University of Sarajevo, Sarajevo Bosnia and Herzegovina1
Public Institution Health Centre of Canton Sarajevo, Sarajevo, Bosnia and Herzegovina2
Faculty of Health Sciences, University of Sarajevo, Sarajevo, Bosnia and Herzegovina3
Farmavita, Sarajevo, Bosnia and Herzegovina, Bosnia and Herzegovina4

Corresponding author: Amira Skopljak, MD, Medical Faculty University of Sarajevo, Cekalusa 90, 71000 Sarajevo, B&H, E-mail: amira_skopljak@yahoo.com

1. INTRODUCTION

Pedobarography is a new method that enables measurement of pressure between the foot and the floor during dynamic loading. Pedobarography analysis shows the distribution of plantar pressure of the foot. Data collection must be standardized so that they can be analyzed and follow the results for each patient, as well as compare them with certain standards.

In addition to clinical examination of the patient, in this manner we get very useful information about the state of the foot and the type of load in certain phases of walking. All this is possible thanks to the invention of electronic sensors installed in a specific platform for walking. Everything is directly connected to computer system programmed to perform analysis of the foot (1). By software analysis we obtain three-dimensional images of foot and distribution of pressure in particular areas of the foot with the same pressure, as well as topographic linkage, so we can determine certain “hot” and “cold” zones of low and high pressure.

Based on the diagnosis in terms of pedobarography in combination with Computer Assisted Design (CAD) software can be constructed a pad using robot machines and Computer Assistant Machine (CAM) in a modern way. The hardness and type of material for the production of orthopedic insoles is selected individually based on clinical picture, the findings of pedobarography and need to reduce load on certain parts of the foot (2).

Pedobarography in diagnosis is used in case of walk disorders after surgery of the hip and knee, as well as in patients with the consequences of stroke. It is important to highlight the clinical application of pedobarography in diabetology (decrease painful sensations in the foot), sports medicine (overuse syndrome), treatment of foot deformities and rehabilitation.
The foot is exposed to high static and dynamic forces of the load, which can lead to disharmony of muscle strength and load which lead to appearance of overuse injuries. It is known that the plantar surface of the foot is the most common place for occurrence of foot ulcerations. In studies that dealt with the prevalence of risk factors for foot ulcerations, it was noted that different types of foot deformity can lead to increased plantar pressure, bat and claw fingers in numerous studies singled out not only as the most common, but also as factors of structural changes with consequent increased load in certain regions on the plantar side of the foot \(3,4\). The presence of sensory neuropathy has been described as the most important risk factor \(5\).

The study by Duffin A.C. indicated that elevated plantar pressure and/or plantar callus (bumps, thickening; lat. plantar callus) has a quarter of young people with diabetes (at age from 11-24 years), which may be a place of high risk to development of foot problems in adulthood \(6\).

Biomechanical changes increase the exposure of individual regions for creating blisters, fissures and deformities. Limited mobility of the joints is a common manifestation in patients with diabetes mellitus. About 30% of diabetics have limited movements of large and small joints. Boulton and Research Association for diabetic foot and risk for the generation of ulcers state that 51% of patients with diabetes and neuropathy have inadequate plantar foot pressure \(7,8\). Recording of risk for foot ulcerations in diabetic patients is central to any plan and program of prevention of nontraumatic amputation of the lower extremities.

Many strategies are used to reduce the maximum pressure during walking trough relief or total contact (insoles, comfortable walking shoes). Information on plantar pressure is useful in predicting the occurrence of ulceration and determining the risk spots. In the treatment of any pathological condition or disease, in addition to reaching the target or the best possible values of certain parameters, it is very important to ensure the patient’s quality of life. Quality of life has for long been recognized as an important indicator of the effects of medical treatments for chronic diseases.

Timely diagnosis and application of individual robot made orthopedic insoles can achieve morphological and functional changes in the foot. Morphological are manifested by adjusting the deformity of the foot and functional in the treatment and prevention of pain.

2. GOAL

To demonstrate the advantages of pedobarography as new diagnostic and rehabilitation method in clinical practice and prevention programs.

3. MATERIAL AND METHODS

This prospective study included 100 patients with diabetes mellitus type 2. Research was conducted at the Primary Health Care Center of the Sarajevo Canton and the Center for Physical Medicine and Rehabilitation. The test parameters were: balance test–symmetric load test, the number of comorbidities, clinical examination of foot deformities, sensory evaluation of distal symmetric polyneuropathy using the test with 10g monofilament and HbA1c. From the total sample 45 patients were selected (group I, \(n = 45\)) aged 50-65 years, which underwent pedobarography (at the appliance Novel Inc., Munich with EMED™ platform) and robotic fabrication of individual orthopedic insoles, followed by control pedobarography after six months of robot made of individual orthopedic insoles application. Plantar pressure was determined using standard pedobarography diagnostic, computer recorded parameters: peak pressure (kPa), force (N) and area (cm). We analyzed the association between the studied parameters. Completed was also a detailed examination of the foot in all subjects at baseline according to the recommendations for the management of diabetes mellitus \(9\).

The clinical examination of a foot deformity included a detailed examination of the feet, where the deformity was found in the form of hallux, the valgus or varus position, flat feet, thickened foot, claw- deformed fingers. Recorded were three groups: patients without deformities, with less or up to two foot deformities, and a third group of respondents who had more than or three deformities.

4. RESULTS AND DISCUSSION

In the total sample of 100 respondents analysis of average age indicates that respondents who underwent pedobarography test (\(N=45\)) had an average age of 58.2±4.6 years with a minimum of 50 and maximum of 65 years, and Group II average of 60.4±14.7 years with a minimum of 34 and max-
It is noted that the majority of respondents have a deformity in form of flat feet 66%, valgus position of the foot 57%, and thickened feet. The study by Bokan V. which analyzed the presence of foot deformities in diabetic patients showed major presence of valgus 40% and other deformities are approximately present in same proportion (13). In the total sample, the average number of foot deformities was 2.84. In the total sample, 63 patients had three or more foot deformities. The analysis of the number of deformities shows that they were significantly more represented in the group of patients which underwent pedobarography (p<0.05) or in 73.3%; three or more, compared to 54.5% with three or more deformities in Group II.

The average HbA1c value in the total sample was 7.783±1.58%; Control 6.96%. The presence of sensory neuropathy has been described as the most important risk factor (14). Test with 10g monofilament shows that the respondents in Group II had a higher average value (2.98±2.6) compared to the patients in group I (2.24±2.3), but without statistically significant differences between groups (p>0.05).

The diagnosis of foot position can clarify findings which by clinical evaluation are not always possible. Pedobarography analysis shows precisely these differences that are very important in the design and production of orthopedic insoles. A very frequent finding is asymmetry between left and right foot. It can be caused by trauma, antalgic gait, shortening of the lower extremities, but also the irregular position of the skeleton. Pedobarography is the electronic measurement of foot load (15,16). In addition to clinical examination of the patient, so we get very useful information about the state of

---

**Table 1. Distribution of respondents in relation to the balance test. χ²=0.952; p=0.223**

| Balance test | Group I | Group II | Total |
|--------------|---------|----------|-------|
| Normal       | 32      | 34       | 66    |
| %            | 71.1    | 61.8     | 66.0  |
| Altered      | 13      | 21       | 34    |
| %            | 28.9    | 38.2     | 34.0  |
| Total        | 45      | 55       | 100   |
| %            | 45.0    | 55.0     | 100.0 |

---

**Table 2. The presence of foot deformity**

| Hallux       | Group I | Group II | Total |
|--------------|---------|----------|-------|
| N            | 21      | 18       | 39    |
| %            | 46.7    | 32.7     | 39.0  |
| Valgus       | 29      | 28       | 57    |
| z²=2.021; p=0.112 | 64.4  | 50.9     | 57.0  |
| %            | 40.0    | 40.0     | 40.0  |
| Varus        | 18      | 22       | 40    |
| z²=2.0001; p=0.581 | 40.0  | 40.0     | 40.0  |
| %            | 66.7    | 65.5     | 66.0  |
| Flatfeet     | 30      | 36       | 66    |
| z²=0.016; p=0.535 | 66.7  | 65.5     | 66.0  |
| %            | 40.0    | 76.4     | 60.0  |
| Thickened foot| 29     | 31       | 60    |
| z²=0.673; p=0.270 | 66.4  | 56.4     | 60.0  |
| %            | 56.4    | 56.4     | 60.0  |
| Claw toes    | 11      | 13       | 24    |
| z²=0.009; p=0.554 | 24.4  | 23.6     | 24.0  |

---

**Table 3. Classification of polyneuropathy on the basis of the test with 10g monofilament. χ²=2.341; p=0.505**

| Test with 10g monofilament | Group I | Group II | Total |
|---------------------------|---------|----------|-------|
| Without neuropathy        | 8       | 13       | 21    |
| %                         | 26.7    | 40.0     | 33.3  |
| Mild polyneuropathy (1-3) | 26      | 31       | 57    |
| %                         | 57.1    | 55.5     | 56.0  |
| Moderately severe polyneuropathy (4-6) | 8     | 13       | 21    |
| %                         | 17.8    | 23.6     | 20.0  |
| Severe polyneuropathy (7-9) | 2       | 6        | 8     |
| %                         | 4.4     | 10.9     | 8.0   |
| Total                     | 45      | 55       | 100   |
| %                         | 45.0    | 55.0     | 100.0 |

---

**Table 4. Distribution of respondents in relation to the variable peak pressure, force and area for the Group I (pedobarography)**
The increase in peak pressure was noticed with the increase in the number of foot deformities, although this association was not statistically significant $r=0.155$ and $p=0.308$ ($p>0.05$). Also noticed is the increase in area with increase in the number of foot deformities, although this association was not statistically significant $r=0.238$ and $p=0.115$ ($p>0.05$).

The research by Burns, J. et al, in the results showed a statistically significant association of who complained to the stronger pain in the feet had higher values of peak pressure and time pain and plantar pressure in patients with foot deformities, or patients with foot deformities pressure or pressure time integral. Gait analysis and pressure was made on the EMED-SF Novel platform (19).

Results of this study show that patients who at baseline had a painful sensations (registered by Test Symptom Score test), after six months in the Group I, after application of the individual robot made orthopedic insoles, have a highly significant reduction in total symptoms of diabetic polyneuropathy ($p<0.05$), especially significantly less painful sensations, which interfered with the movement and other physical activities of patients.

By increasing the number of negative fields in testing sensitivity increases peak pressure. There was a statistically significant correlation between peak pressure and the test with 10g monofilament with $r=0.317$ and $p=0.034$ ($p<0.05$).

Total Symptom Score Test (pain, burning, paresthesia, insensitivity) between the groups during the first and second measurements showed that after the second measurement there is a statistically significant difference in of sense significantly lower values in pedobarography group ($p<0.05$).

This study did not find significant correlation between foot deformity, sensory polyneuropathy and plantar pressure ($p>0.05$).

5. CONCLUSION

New diagnostic technology, pedobarography and manufacturing of orthopedic insoles allow the prevention and re-
duction of symptoms, reducing load on the foot, and are of great importance for the patient suffering from diabetes in prevention programs.

CONFLICT OF INTEREST: NONE DECLARED.

REFERENCES

1. Žvorc M. Dijagnostički postupci kod promjena na stopalu, Acta med Croatica, 2011: 64(supl.1): 15-25.
2. Muftić M, Zubčević H, Kasumagić Z. Pedobarografija u prevenciji i teretmanu sindroma prenatalja. Prvi balneološko-reumatološki simposium i Bosni i Hercegovini. Zbornik rada, Sarajevo: 2011: 109-110.
3. Smith EK, Commean KP, Mueller MJ, Robertson DD, Pilgram T, Johnson J. Assessment of the diabetic foot using spiral computed tomography imaging and plantar pressure measurements: a technical report. J Rehabil Res Dev. 2000: 37(1): 37-40.
4. Kwon OY, Mueller MJ. Walking patterns used to reduce forefoot plantar pressures in people with diabetic neuropathies. Phys Ther. 2001; 81(2): 828-835.
5. Courtemanche R, Teasdale N, Boucher P Fleury M, Lajoie Y, Bard CH. Gait problems in diabetic neuropathic patients. Arch Phys Med Rehabil. 1996: 77: 849-855.
6. Duffin AC. Assessing and treating high plantar pressure and callosus in young people with diabetes. Clinical Biomechanics. 2001; 16(9): 834-835.
7. Abouaesha F, van Schie CH, Griffths GD, Young RJ, Boulton AJ. Plantar tissue thickness is related to peak plantar pressure in the high-risk diabetic foot. Diabetes Care. 2001: 24(7): 1270-1274.
8. Tesfaye S, Kempleil P. Painful Diabetic Neuropathy. Diabetologia. 2005; 48(5): 805-807.
9. Anonynnuo. American Diabetes Association (ADA);. VI. Prevention, Management of Complications. Diabetes Care. 2011: 34 (suppl 1): S27.
10. Simoaneau GG, Ulbrecht JS, Derr JA, Becker MB, Cavanagh PR. Postural instability in patients with diabetic sensory neuropathy. Diabetes care. 1994: 17; 1411-1421.
11. Cavanagh PR, Simonoueau GG, Ulbrecht JS. Ulceration, unsteadness, and uncertainty: the biomechanical consequences of diabetes mellitus. J Biomech.. 1993: 26 (Suppl 1): 23-40.
12. Uccioli L, Giacomini P,G, Monticone G, Magrini A, Durola L, Bruno E, Parisi L, Di Girolamo S, Menzinger G. Body sway in diabetic neuropathy. Diabetes care. 1995: 18: 339-344.
13. Bokan V. Faktori rizika za nastanak ulcercije stopala kod dijabetičara- senzitivna neuropatija i deformiteti stopala. Acta Medica Medianae. 2010: 49(4): 19-22.
14. Courtemanche R, Teasdale N, Boucher P Fleury M, Lajoie Y, Bard CH. Gait problems in diabetic neuropathic patients. Arch Phys Med Rehabil. 1996: 77: 849-855.
15. Duckworth T. Pedobarography. In: Helal B,Wilson D (editors). The Foot. Edinburgh, London, Melbourne, New York: Churchill Livingstone; 1988: 108-130.
16. Pećina M, Obrovac K, Pećina HL, Jelić M. Electronic measurement system for recording and evaluating dynamic plantar pressure distribution. In: Magjarević R, ed., Biomedical measurement and instrumentation: proceedings/8th International IMEKO Conference on Measurement in Clinical Medicine & 12 th International Symposium on Biomedical Engineering, Dubrovnik, 1998; Zagreb; KoREMA: 8-56.59.
17. Buljat G, Obrovac K, Obrovac Vuković J, Pećina M, Perović D, Keja Z et al. Pedobarographic diagnosis of plantar pressure distribution in patients having calcaneal fractures. In: Magjarević R, ed., Biomedical measurement and instrumentation: proceedings/8th International IMEKO Conference on Measurement in Clinical Medicine & 12 th International Symposium on Biomedical Engineering, Dubrovnik. Zagreb: KoREMA; 1998: 8-48.
18. Sicco A. Bus, Antony de Lange. A comparison of the 1-step, 2-step, and 3-step protocols for obtaining barefoot plantar pressure data in the diabetic neuropathic foot, Clinical Biomechanics. 2005; 20(9): 892-899.
19. Burns J, Crosbie J, Hunt A, Ouvrier R. The effect of pes cavus on foot pain and plantar pressure. Clinical Biomechanics. 2005; 20(9): 877-882.