ORIGINAL PAPER

Pedobarography in Diagnosis and Clinical Application

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ABSTRACT

Introduction: Pedobarography as a new diagnostic tool enables measuring the pressure between the foot and the floor during dynamic loading. Dynamic analysis of the foot shows advantage over static analysis due to its capabilities for detecting high load points in certain diseases and in certain phases of walking. Pedobarography as a new method in the context of rehabilitation include wide range of clinical entities. **Goal:** To show the advantages of pedobarography as new diagnostic and rehabilitation method in prevention programs. **Material and methods:** A prospective study included 100 patients with diabetes mellitus type 2. Research was conducted in the Primary Health Care Center of the Sarajevo Canton and the Center for Physical Medicine and Rehabilitation. The test parameters were: Test of balance–symmetric load for the test, the number of comorbidity, clinical examination of foot deformity, test with 10 g monofilament, HbA1c. From the total sample 45 patients (Group I) were selected, aged 50-65 years, which underwent pedobarography (on the appliance Novel Inc., Munich with EMED™ platform) and robotic fabrication of individual orthopedic insoles, followed by control pedobarography. Plantar pressure was determined using standard pedobarography, computer recorded parameters: peak pressure (kPa), force (Ns), area (cm). **Results:** The average age of the respondents was 59.4±11.38 years; altered results on the balance test were present in 34% of patients; 61% of respondents have ≤2 comorbidity. In the total sample, the average number of foot deformity was 2.84. Flat feet have 66% of respondents, and valgus position 57%. The average HbA1c values were 7.783±1.58% (min.5–max.15.0). All subjects (45) after the first, and after the second measurement of peak pressure, have values above 200 kPa, or are in the designated zone of peak pressure that needs to be corrected. In a study was determined the correlation between the number of deformities and peak pressure, the number of deformities and the area upon which plantar pressure act, test with 10g monofilament and peak pressure. **Conclusion:** Within the framework of prevention programs early diagnosis, detection of sensitivity disorders, adequate treatment and taking load from the feet with the help of pedobarography, are of great importance for the patient suffering from diabetes

Key words: Pedobarography, diagnostics, clinical application

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.

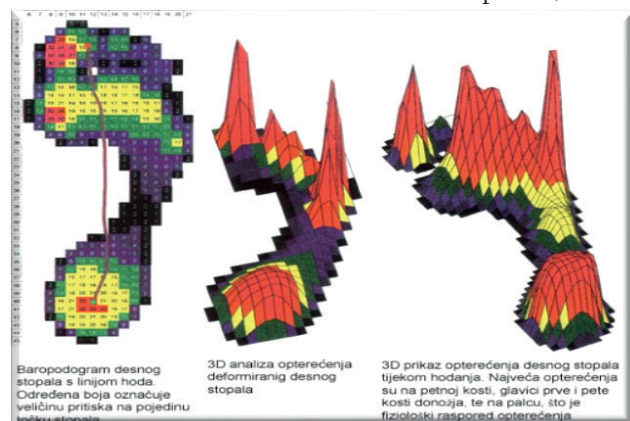In addition to clinical examination of the patient, in this manner we get very useful information about the state of the foot and the type of load in certain phases of walking. All this is possible thanks to the invention of electronic sensors installed in a specific platform for walking. Everything 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 (de-
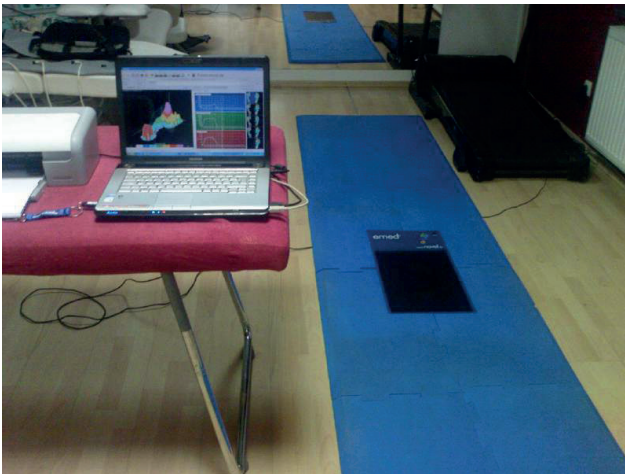

Figure 1. *Pedobarograph and 3D display of foot load*

Figure 2. *Measurement platform connected to a computer system*

crease 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).

Figure 3. *The patient during the diagnostic analysis of walk on EMED platform*

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 (Ns) 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 maximum of 87 years, but without statistically significant differences between groups (t=0.978; p>0.05). In Group II were the respondents who did not underwent pedobarography and which included 55 participants. At the start of the study in Group I was included 47 and in Group II 60 patients, but in the course of research, due to non-compliance with the program seven respondents were excluded.

It is known that people with diabetes and with diabetic polyneuropathy have trouble controlling balance, due to damage to their sensibility in the foot (10,11,12). In our research, balance test in the group pedobarography–Group I with a grade altered had 28.9% of the respondents in relation

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

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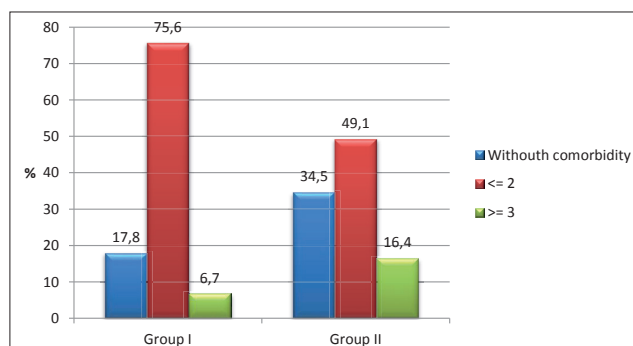

Figure 4. *Frequency of comorbidity*

to the Group II (38.2%), this difference was not statistically significant (p>0.05).

Also analyzed is number of comorbid diseases (gonarthrosis, coxarthrosis, hernia disc, spondylosis L/S spine, and abbreviations of the lower limbs). There was a statistically significant difference between the groups according to the number of comorbidity, so in the Group II was recorded a higher number of patients without comorbidity as well as respondents with

		Group		Total
		Group I	Group II	
Hallux χ2=2.021; p=0.112	N	21	18	39
	%	46.7	32.7	39.0
Valgus χ2=1.850; p=0.123	N	29	28	57
	%	64.4	50.9	57.0
Varus χ2=0.0001; p=0.581	N	18	22	40
	%	40.0	40.0	40.0
Flatfeet χ2=0.016; p=0.535	N	30	36	66
	%	66.7	65.5	66.0
Thickened foot χ2=0.673; p=0.270	N	29	31	60
	%	64.4	56.4	60.0
Claw toes χ2=0.009; p=0.554	N	11	13	24
	%	24.4	23.6	24.0

Table 2. *The presence of foot deformity*

more than 3 comorbid conditions, while in Group I a larger number of patients with one or two comorbidities (p<0.05) .

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

			Group		Total
			Group I	Group II	
Test with 10g monofilament	Without neuropathy	N	12	11	23
		%	26.7	20.0	23.0
	Mild polyneuropathy (1-3)	N	23	25	48
		%	51.1	45.5	48.0
	Moderately severe polyneuropathy (4-6)	N	8	13	21
		%	17.8	23.6	21.0
	Severe neuropathy (7-9)	N	2	6	8
		%	4.4	10.9	8.0
Total		N	45	55	100
		%	45.0	55.0	100.0

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

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

		Mean	N	SD	SEM	t	p
Pair 1	Peak pressure (kPa) 1 measurement	474.38	45	188.389	28.083	-3.337	0.002
	Peak pressure (kPa) 2 measurement	577.60	45	209.545	31.237		
Pair 2	Force (Ns) 1 measurement	621.82	45	164.214	24.480	-1.623	0.112
	Force (Ns) 2 measurement	662.13	45	125.788	18.751		
Pair 3	Area (cm) 1 measurement	128.87	45	13.458	2.006	2.964	0.005
	Area (cm) 2 measurement	124.00	45	15.801	2.356		

Table 4. *Distribution of respondents in relation to the variable peak pressure, force and area for the Group I (pedobarography)*
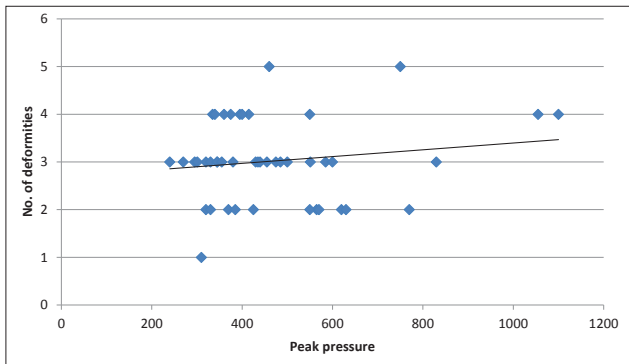
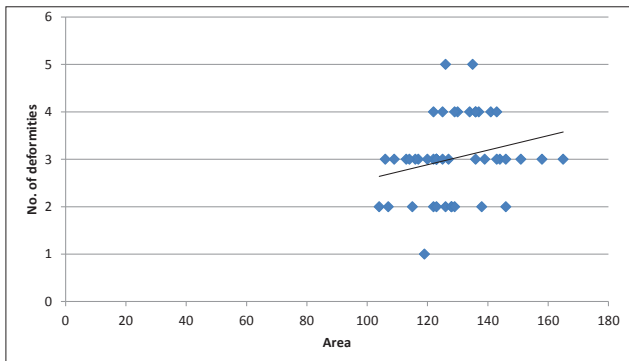Figure 5. *Correlation between the number of deformities and peak pressure*

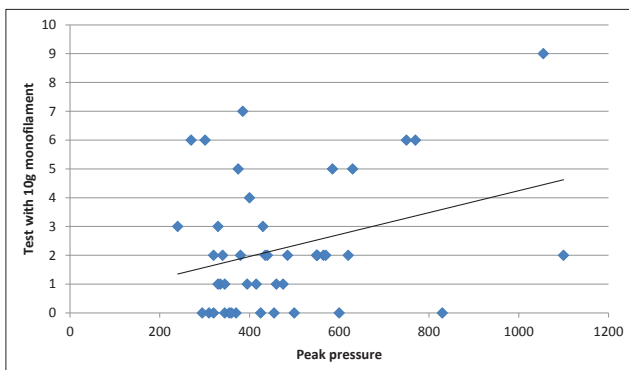Figure 6. *The correlation between the number of deformities and area; first measurement*

Figure 7. *Correlation of test with 10 g monofilament results and peak pressure*

foot load (15,16). In addition to clinical examination of the patient, so we get very useful information about the state of the foot and the type of load in certain phases of walking (17). Prints o the feet can be seen by pedoscope and register as plantograph. Walk or walking, can be studied only by electronic measurement of the individual phases.

Pedobarography as new diagnostic method has great significance. With clinical examination and pedobarography analysis it is possible to diagnose and make complete diagnosis in certain diseases.

All respondents (45) after the first, and after the second measurement of peak pressure, have values above 200 kPa, or are in the designated zone of peak pressure that needs to be corrected.

Sicco A. Buss and Antony de Lange in their work have shown that there are significant differences in the determination of regional peak pressure and pressure-time between the three protocols (1- step protocol; 2- step protocol; 3-step protocol), or the method for setting the plantar pressure in di-

abetic patients with diabetic polyneuropathy. Diabetic polyneuropathy were examined and diagnosed by a test of the vibrating fork and 10 g monofilament. The regional analysis of plantar pressure, time pressure and contact time were determined in six anatomical regions of the feet on EMED pressure platform (18).

In our patients, we applied the 1- step protocol, which means that the respondents when determining the parameters mentioned above made the first step on the EMED platform.

The increase in peak pressure was notices 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 pain and plantar pressure in patients with foot deformities, or patients with foot deformities who complained to the stronger pain in the feet had higher values of peak pressure and time 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).

Figure 8. *A patient with amputation of toes*

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 reduction 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.

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