The evaluation of plantar pressure distribution in Type Ⅱ diabetic patients and non-diabetic adults in China

Luming Yang[1], Petr Hlaváček[1], Jin Zhou[2], Wuyong Chen[2], Bo Xu[2], Surui Liu[3]*

[1] Faculty of Technology, Tomas Bata University, Zlin 760 01, Czech Republic;
[2]National Engineering Laboratory for Clean Technology of leather Manufacture, Sichuan University, Chengdu 610065, P. R. China;
[3]Chongqing Academy of Metrology and Quality Inspection, Chongqing 400020, P.R. China

Abstract: Plantar pressures in Type Ⅱ diabetic patients and control adults during normal walking were compared in this study. A total of 70 (45♀+25♂) type 2 diabetic patients without neuropathy (aged 63.6±7.6 years; BMI 24.3±2.9; duration of diabetes 12.3±6.9 years) and 70 (45♀+25♂) non-diabetic adults (aged 62.5±8.6 years; BMI 22.4±2.5) in China were recruited. Plantar pressures were collected by EMED system (Novel, Germany). All participants were required to walk barefoot at a self-selected speed, the parameters of peak pressure and contact areas were collected. During analysis ten plantar regions were identified: hind foot, midfoot, the first (MH1), second (MH2), third (MH3), fourth (MH4), fifth (MH5) metatarsals, big toe, second toe and toes 345. Only data from the right foot was analyzed, independent samples *t*-tests were used to compare dynamic variables between two groups. **Results:** No significant differences of peak pressures were found between male and female. Except for midfoot, second toe and toe 345 regions, no significant differences of peak pressures were found in other seven regions between two groups. Pearson correlations were performed between BMI and peak pressures for the foot across both groups. No correlation was found between BMI and peak pressure.

Key words: diabetes type 2; plantar pressure; pedobarography

1 Introduction

Diabetes mellitus is a disease that is ranked globally into the group of "civilized" affliction. The first mention of it dates from 1552 when it was described as a rare illness, which is accompanied by great thirst and the caused of which is unknown.

There is a world-wide epidemic of Type Ⅱ diabetes mellitus. The total number of people with diabetes is projected to rise from 171 million in 2000 to 366 million in 2030 [1]. There are 40 million people with diabetes in China [2].

The incidence of diabetes is increasing as are its associated complications, and one important complication is foot ulcer development. Higher plantar pressure has been prospectively linked to ulcer formation in those with diabetes [3]. It has been well documented that pressures under the foot in those with diabetes are higher than those without diabetes [4].

Some studies have reported no significant differences in term of plantar pressure between diabetic patients with neuropathy and control diabetic patients. Few studies have examined plantar pressure distribution in Type Ⅱ diabetic patients without neuropathy, especially in Chinese population. More studies are needed in this field.

The purpose of our study was to investigate the distribution of plantar pressure in type 2 diabetic patients and compare them to the healthy population.

*Corresponding author. Phone: +42-(0)776491564. E-mail: yangluminglulu@hotmail.com

2 Experimental

2.1 The subjects

Seventy type Ⅱ diabetic patients without neuropathy and foot deformity (45 female, 25 male, and duration of diabetes 12.3 ± 6.9 years) were recruited from the Sichuan University &West China Hospital. Neuropathy was confirmed by a loss of protective sensation on the plantar surface of the foot, as determined by the inability to feel the 10-g Semmes-Weinstein monofilament on the hallux of both feet. Seventy healthy subjects (45 female, 25 male) were recruited in Sichuan University, China. Body weight and height was measured and body mass index (BMI) was calculated.

$$BMI = \frac{m}{v^2}$$

Where: m – body weight of patient [kg], v – body height of patient [m].

An informed consent was obtained from each participant.

2.2 Data acquisition

A capacitive pressure distribution platform (EMED AT, Novel GmbH), collecting at 50 Hz was used to collect plantar pressure patterns. Foot pressure distribution was measured during barefoot walking at an individual normal walking speed. Three trials were collected for both the left and right foot; individual means of all the three repeated trials for right foot were calculated.

All subjects were given time to familiarize themselves with the process of walking over the platform [5]. Subjects were asked to walk "normally" instead of being concerned on the platform [6].

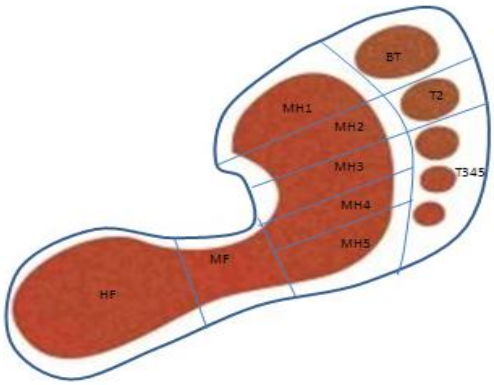

Fig.1 Mask applied to divide the foot into 10 marks

Data analysis was conducted with the Novel Database Pro software package (Novel GmbH). In order to achieve a detailed description of foot loading during walking, the parameters of peak pressure, pressure-time integral, maximum force, contact time and contact areas were collected. The foot of each subject was divided into 10 marks: hind foot, midfoot, the first (MH1), second (MH2), third (MH3), fourth (MH4), fifth (MH5) metatarsals, big toe, second toe and toes 345 (see Fig.1).

2.3 Analysis and statistics

The characteristics of the type Ⅱ diabetic and controlled subjects were compared by independent sample *t* test. Pearson correlations were performed between BMI and peak pressures of all study participants. Only data from the right foot was analyzed, in order to satisfy the independence assumption of statistical analysis [7]. Statistical analysis was performed by using SPSS for windows (SPSS, Inc., Chicago, IL)

3 Results and discussion

3.1 General information

Tab. 1 The characteristics of all subjects

Types	Diabetic group	Control group
Age (year)	63.6±7.6	62.5±8.6
Gender	45 female, 25 male	45 female, 25 male
Weight (kg)	60.7±9.9	57.1±8.1*
Height (m)	1.58±0.8	1.59±0.7
BMI	24.3±2.9	22.4±2.5**

**P<0.05, **P<0.001*

One hundred and forty study participants were investigated, seventy belonged to diabetic subjects and seventy belonged to the control subjects. The characteristics of the study participants were summarized in the Table 1. The body weight (P<0.05) and BMI (P<0.001*)* are significant different between two groups.

3.2 Influence of gender

Tab. 2 Comparison of peak pressure distribution between genders

Peak pressure (kPa)	Male	Female
Hind foot	228.1±72.5	231.0±83.4
Midfoot	109.4±44.7	127.8±89.5
MH1	252.1±136.5	232.1±149.8
MH2	283.9±95.9	297.9±116.1
MH3	283.2±93.5	289.6±92.1
MH4	224.6±87.1	222.4±81.5
MH5	276.5±172.4	274.6±156.0
Big toe	329.7±157.9	307.8±135.8
Second toe	145.7±71.7	126.7±67.5
Toe 345	124.2±58.6	118.9±65.7

No significant differences of peak pressures were found between male and female, therefore, subjects of both genders were combined into one group and all subjects were divided into two groups: diabetic group and control group.

3.3 Plantar pressure distribution

Tab. 3 Comparison of dynamic pedobarography values between the groups

Types	Diabetic group	Control group
Contact area/TO (cm^2)	110.9±14.2	117.1±13.1*
Contact time/TO (ms)	1122.3±236.4	1071.4±232.9
Maximum force/TO (N)	619.4±99.2	628.9±74.7
Peak pressure/TO (kPa)	484.6±134.7	491.9±152.5
Pressure-time integral/TO (kPa*s)	283.7±85.5	277.9±112.9

**P<0.05*

A comparison of mean values of contact area, contact time, maximum force, peak pressure and

pressure-time integral is displayed in Table 3, indicating significant difference only in the contact area. The peak pressure value of Chinese subject was similar to the previous study in China [8] and lower than other countries in previous researches 614.2 kPa [9], which maybe because of the ethnic difference [10]. It also could be the result of environment differences, such as social economy and lifestyle factors as well as walking habits.

Tab. 4 Comparison of peak pressure distribution between the groups

Peak pressure (kPa)	Diabetic group	Control group
Hind foot	235.0±68.6	224.9±89.2
Midfoot	138.8±100.7	103.7±33.8*
MH1	228.6±124.9	249.9±162.8
MH2	301.1±117.0	284.7±100.8
MH3	289.3±97.4	285.3±87.7
MH4	223.1±91.9	223.2±74.3
MH5	283.5±159.4	267.0±164.2
Big toe	296.9±129.7	224.3±155.5
Second toe	117.2±71.2	149.8±63.9*
Toe 345	103.5±64.8	138.0±56.7*

**P<0.05*

The distribution of the peak pressure for diabetic subjects was different between two groups, for diabetic group was MH2 > Big toe > MH3 > MH5 > Hind foot > MH1 > MH4 > Midfoot > Second toe > Toe 345; for control group was Big toe > MH3 > MH2 > MH5 > MH1 > Hind foot > MH4 > Second toe > Toe 345 > Midfoot. As we can seen from Table 4, except for midfoot, second toe and toe 345 regions, no significant differences of peak pressures were found in other seven regions between two groups (P<0.05).

3.4 Correlation

Among the dynamic parameters, BMI was only found to have positive correlation with total maximum force (r=0.53, P=0.000), it was similar to the previous results [11], no correlation was found with the peak pressure. Age has been previously reported as being associated with decreased heel and hallux pressure [12], but in this study, it was associated with the pressure-time integral for the MH1 (r=0.029, P=0.000) and MH5 (r=0.186, P=0.028).

4 Conclusions

This study was undertaken to compare the distribution of plantar pressure in Type Ⅱ diabetic patients and non-diabetic adults in China. No significant difference of peak pressure was found between male and female. The distribution of plantar pressure was different between diabetic group and control group. No correlation was found between BMI and peak pressure and age was associated with the pressure-time integral for the MH1 and MH5. It can be a reference for the plantar pressure investigation of Chinese diabetic patients. It is also confirmed that diabetic patients should be informed to pay more attention to their foot; the higher local pressure will be dangerous in their normal walking and maybe special footwear is needed for them. Anyway, there are a number of limitations of this study; the number of subjects should be expanded in further study.

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