PREDICTIVE FACTORS OF GAIT IN NEUROPATHIC AND NON-NEUROPHATIC DIABETIC PATIENTS

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ABSTRACT

Objective: The purpose of this study was to analyze the range of movement of the ankle and the vertical ground reaction force involved in gait among diabetic patients with and without peripheral neuropathy. Sample and Method: 36 individuals were divided into three groups: Control group – CG: 10 individuals without diabetes, Diabetic group – DG: 10 individuals with diabetes without peripheral neuropathy and Neuropathy, and Diabetic neuropathic group – DNG: 16 individuals with diabetes and peripheral diabetic neuropathy. Gait - AMTI® OR6/6m and range of tibiotarsal joint movement – System Vicom 640® was carried out in all the participants. Results: The first and second vertical ground reaction force peaks were statistically higher in the neuropathy group, and the range of ankle motion was lower in the Diabetes and Neuropathy groups. Conclusion: The range of movement of the tibiotarsal joint is lower in diabetics, regardless of the presence or absence of peripheral neuropathy, and diabetics with peripheral neuropathy show an increase in the first and second vertical ground reaction force peaks during walking.

Keywords: Diabetes Mellitus. Diabetic neuropathies. Gait.

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INTRODUCTION

Hyperglycemia, in individuals with diabetes, causes systemic and local complications, which represent a negative economic impact in all countries.[1-4] Peripheral neuropathy exhibits prevalence of 20% in adult patients, and results in alterations in the gait pattern and cutaneous lesions in a significant portion of cases.[5-9]

The main manifestations encountered in diabetic patients with peripheral neuropathy are: burning sensation, hyperesthesia or paresthesia on the affected limbs, associated with reduction of protective sensibility of the feet.[5-8] The change in sensibility modifies the gait pattern of these patients, as it decreases the transmission of proprioceptive information – plantar neuroceptors - essential for normal gait.[9]

Studies comparing the gait of patients with peripheral diabetic neuropathy with individuals without diabetes showed alterations in load distribution and in the range of movement of the ankle joint; leading to overload at points of the plantar surface of the foot during contact with the ground and an increase in the risk of development of skin ulcers on these points.[10-13]

Shaw et al.[14] assessed 181 individuals and found an increase in the vertical ground reaction force in diabetics in relation to the control group without diabetes.

The reduction of visual acuity and the limitation of joint movement are factors that heighten the risks of cutaneous lesions.[15-17] The limitation of range of joint movement mainly affects individuals with type 1 diabetes, and is related to the increase of glycosylated hemoglobin rates and the duration of diabetes. Prevalence increases with smoking and age.[17,18]

The reduction of range of movement of the ankle joint increases the vertical ground reaction force in the feet during gait and results in metatarsalgia.[19,20]

Muller et al.[21] demonstrated that range of movement of the ankle joint is smaller in patients with diabetic neuropathy than in those without diabetes.

However, there is no consensus in literature regarding alterations of gait variables between diabetics with peripheral neuropathy and without this complication.

Therefore, the aim of this study is to analyze the range of mo-

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Study conducted at the Orthopedics and Traumatology Institute of USP
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vement of the ankle, the vertical ground reaction forces involved in the gait of diabetic patients with and without peripheral neuropathy.

CASUISTRY AND METHODS

After approval by the Commission of Ethics for Analysis of Research Projects - CAPPesq of the Clinical Management of Hospital das Clínicas and of Faculdade de Medicina da Universidade de São Paulo; Twenty-six patients from the Foot and Ankle Group Outpatient Sector of this institution and ten healthy volunteers, were assigned to 3 groups for analysis of range of tibiotarsic joint movement and of vertical ground reaction peaks during gait:

Control Group - CG: 10 individuals - 6 women 4 men - without diabetes.

Diabetes Group - DG: 10 individuals - 7 women and 3 men – diabetic patients without peripheral neuropathy.

Neuropathy Group - NG: 16 individuals - 11 women and 5 men - diabetes and peripheral diabetic neuropathy patients.

The presence of diabetic neuropathy was verified through propedeutics with monofilament of 10 grams and tuning fork of 128 HZ according to the Michigan protocol,[22-24] which allows evaluation of protective sensibility with implication of the thin and thick fibers.[25]

The evaluation of peripheral vascular disease was performed through palpation of the foot pulse and posterior tibial pulse, and echo-doppler for obtainment of the tibiobrachial index (TBI)[25-27]

Negative Inclusion Criteria:

1. Neuroischemic diabetic foot
2. Charcot's neuroarthropathy
3. Patient with deambulation impairment.

Ground reaction force platform

The ground reaction force platform (AMTI® OR6/6) is a dynamometry instrument used to measure the dynamic variables of movement, allowing the quantification of mechanical loads, through gait analysis. The equipment allows evaluation of the vertical ground reaction force at its maximum frequency, corresponding to 1000 Hertz (Hz).

Vicom 640® System

The movements were captured for kinematic analysis with the Vicon® system, using 4 cameras (Mcam2). The range of movement studied was that of the tibiotarsic joint.

Fourteen millimeter reflective markers were adhered to anatomical points to represent the segment to be analyzed. In this manner, the studied segment was reconstructed in the software and the force platform was synchronized.

The cameras used for filming the range of movement worked with maximum speed capacity at the frequency of 250 Hz of data capture.

Kinetics

As regards the kinetic variables, the first and second vertical ground reaction force peaks were used in this study.

The first peak corresponds to the weight bearing, at the beginning of the gait support phase, on the hind foot. The second peak corresponds to the force made in the forefoot to propel the limb and to commence the swing phase of the gait.[28] For the analyses, the values of both peaks were demonstrated in percentage of weight of the volunteers.

Kinematics

The range of movement of the ankle joint - kinematic variable - was analyzed in the sagittal plane, divided into dorsiflexion and plantar flexion. For the gathering of this information, the reflective markers were placed at the anatomical points corresponding to the fibular head, lateral malleolus and dorsal surface of the metatarsophalangeal joint.[29]

Procedures

At first markers were adhered at the predetermined anatomical points and the volunteers were filmed walking along a track where the force platform was positioned. The volunteers were asked to walk at their habitual speed as they usually do in the street. After adaptation of the patients to the evaluation environment, their left feet were positioned to touch the force platform during gait. Ten valid incursions were recorded.

The vertical ground reaction force values were normalized by the body weight of each patient and by the total duration of the support of the limb to be analyzed.

The Matlab® mathematical program was used to interpret the force platform and filming data. This program determined the mean and the standard deviation of the values obtained for the variables studied in the 10 valid incursions, for each volunteer.

Statistical Analysis of Results

A statistical analysis of results was conducted through Variance Analysis (ANOVA) with Tukey's post test, with significance level of 5%.

RESULTS

The Control, Diabetes and Neuropathy groups present normal distribution for age by the Kolmogorov-Smirnof test, with $p=0.7309$ by the Student's t-test and $p=0.7257$ by the Mann-Whitney test, and are therefore comparable. They also present statistical compatibility for gender by the Chi-squared test with $p=0.806$ and Fisher's test with $p=1.000$.

For the Diabetes and Neuropathy groups a similarity can be observed between time of diabetes and of glycated hemoglobin. (Table 1)

The evaluation of vertical ground reaction force peaks shows that the first and the second peak were higher in the NG when compared with the CG and DG. There was no statistical significance in the comparison between the CG with the DG for these variables. (Table 2)

As regards range of ankle movement it can be verified that the groups with patients from the Diabetes and Neuropathy groups experienced a decrease in relation to the Control group. (Table 2)

Table 1 – *Distribution of the means and standard deviations of the anthropometric characteristics, time of diabetes and glycosylated hemoglobin.*

Variable	CG (n=10)	DG (n=10)	NG (n=16)
Age (years)	62 ± 3.77	63 ± 3.92	63 ± 3.89
Mass (kg)	77.8 ± 8.08	78 ± 9.73	78.88 ± 8.13
Height (m)	1.69 ± 0.07	1.68 ± 0.11	1.66 ± 0.07
BMI (kg/m)	27.35 ± 2.52	27.66 ± 2.66	28.75 ± 2.88
Time DM (years)	–	12 ± 1.15	12.13 ± 1.26
Glycosylated Hb (%)	–	7.65 ± 1.42	7.85 ± 1.29

Table 2 – *Distribution of values of the first and second force peak, in percentage of weight, and of the range of movement of the ankle in the studied groups.*

Variables	CG (n=10)	DG (n=10)	NG (n=16)
P1	91.2±4.42	91.8±8.45	103.88±4.82
P2	93.82±5.26	93.63±6.85	106.38±8.33
ROM	29.01±3.29	20.92±3.56	20.24±4.08

DISCUSSION

In the Neuropathy group a significant increase of the first peak of vertical ground reaction force was observed when compared with the DG and CG. Uccioli et al.[30] and Shaw et al.[14] encountered similar results in their studies.

The second peak of the vertical ground reaction force was also statistically higher in the NG when compared with the other two groups. Uccioli et al.[30] obtained similar results. This overload is probably related to the alterations in the intrinsic musculature of the foot, which have dynamic and static alterations overloading the forefoot.[31-33]

The plantar overload in patients with reduced protective sensibility favors the occurrence of cutaneous ulcers and Charcot's arthropathy.[16,34]

The therapeutic shoe especially developed for patients with increase of the first and second peak of vertical ground reaction force is recommended by Long et al.[35] in the prevention of plantar ulcers and joint alterations caused by overload. These shoes with high and wide toe box, soft lining and nonflexible sole, are capable of reducing the mechanical overload on the plantar surface of the foot.[36]

Muller et al.[21] and Akashi[37] did not evidence the alterations of vertical ground reaction force between groups of patients with diabetic peripheral neuropathy and the control group. However, these studies used different methodology. For the Akashi[37] study the volunteers walked along the track containing the force platform for just three valid attempts to assess the vertical ground reaction forces, and in the study by Muller et al.[21], the force platform was adjusted to gather data at a frequency of just 60 Hz, that is, obtaining 60 items of information per second.

This study used a higher frequency to capture the vertical ground force - 1000 Hz - and a higher number of valid attempts - 10.

We also observed that the two vertical ground reaction force peaks had similar behaviors between the groups of patients with Diabetes and the Control group. This was the result found by Katoulis et al.[38]

The range of tibiotarsic movement of the DG and of the NG is statistically inferior. The findings of literature related to limitation of joint mobility are associated with alterations of collagen, with early impairment of the tendons, ligaments and cartilage of the foot and ankle, in patients with diabetes independently of neuropathy.[11,16,39]

According to Santos and Barela[40] and Yavuzer et al.[41], before the clinical diagnosis of Diabetic Neuropathy, diabetic patients can present sensitive and motor alterations, modifying the gait pattern. Accordingly, the similarity of the findings of range of joint movement between the groups of diabetic patients with and without neuropathy - DG and NG, may suggest the presence of subclinical neuropathy in the first group.

Studies on peaks of vertical ground reaction force in individuals with diabetic neuropathy that use therapeutic shoes could contribute in the evaluation of their effectiveness.

CONCLUSION

The range of movement of the tibiotarsic joint is reduced in diabetics, regardless of the presence or absence of peripheral neuropathy, and diabetics with peripheral neuropathy presented increase in the first and in the second peak of vertical ground reaction force during gait.

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