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Research Article

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Plantar pressures character of diabetic patients with the fifth toe deformity

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ABSTRACT

Plantar pressure information is very useful to the diabetic patients' foot health. A lot of pressure measurement studies have carried out on diabetic person. However, quite few could be found to know the diabetic foot's incipient stage such as toe deformity. The purpose of this study was to quantitatively assess plantar pressure associations with toe deformed diabetic patients. Six neuropathic diabetic subjects with the fifth toe deformity, and six age and gender matched neuropathic diabetic controls without deformity, were examined. Dynamic barefoot plantar pressures were measured with Novel EMED pressure platform. Peak pressure and pressure–time integral for each of 7 foot regions were calculated. Peak pressure was significantly higher in the patients with toe deformity at heel, hallux, and other toes regions, when compared with controls. Meanwhile, loading sustained time extend longer in toe regions of deformed group than the controls, and the center of pressure was nearly in the big toe region during toe-off stage. Diabetic subject with toe deformity could cause plantar contact area, pressure and gravity center variety. It shall attach importance to toe deformity situation, because it highly associated with ulcer risk especially in hallux region.

Keywords: Toe deformity; Plantar pressure; Hallux; Gait

INTRODUCTION

It has been estimated that the number of people with diabetes worldwide will surpass 365 million by 2030 [1]. The loading pressure applied to the plantar surface of foot during gait has changed in patients with diabetes mellitus and peripheral neuropathy [2]. Some excessive pressures in feet that lack protective sensations considered as a major risk factor for plantar ulceration[3], which is the most common precursor to lower extremity amputation among persons with diabetes [4]. Peripheral neuropathy can cause the patients emerging with lower limb injury, even disability. The foot injury due to the decreasing foot nerve sensory could easily been overlooked, thus increasing the risk of skin ulcers or damage [5]. Previous study found that early diabetic foot tending to show toe deformity [6, 7], imbalance in lower limb muscles [8], and finally lead to abnormal plantar pressure [9]. When the lesion or dysfunction of the human foot structure, and human movement state changed, plantar pressure and pressure distribution will change consequently [10, 11].

It is clear that the emergence of the diabetic foot is caused by the changes of plantar pressure. When the pressure distribution altered, this can destroy foot blood supply, and finally lead to foot ulceration even amputation. However, there is rare report about toes deformation which is the early signs of diabetic foot deformation and the major reason changes of plantar pressure. Therefore, this study aiming to measure the plantar pressure of diabetes patients whose fifth toe has deformed. Also, identity the characteristic of this toe deformed, hoping to supply some important information for diabetic shoes design to alleviating the pain in patients' deformed feet, reducing the disease incidence of diabetic foot.

EXPERIMENTAL SECTION

Twelve female diabetes patients with toes lesions and twelve age-matched female diabetes patients but healthy foot were selected. Subjects in the experimental group were chosen based on deformity present in the fifth toe of the foot while non-weight bearing. Although their toe has a claw or hammer-shaped deformation, subjects hasn't exhibit of the characteristics of festering, with the ability of walking normally. All subjects' baseline characteristics are summarized in Table 1.

For plantar pressure data measurement, the Novel emed (Novel Gmbh, Munchen, Germany) plate was used. During the test, subjects were asked to walk along 15 meters straightly with the normal speed as usually, measuring plate was locating in the center of aisles. All subjects have three days practicing before the experiment to familiar the walking environment. Plantar area was divided into seven regions, which are heel, mid foot, lateral forefoot, middle forefoot, medial forefoot, hallux and 2-5 toes (other toes). For each region, peak pressure, pressure-time integration and locus of the Center of Pressure were calculated from the six successfully walking trial.

SPSS 17.0 for Windows was used for statistical analysis (SPSS, IL, USA). The differences between measurements in deformed and control subjects were analyzed using a two-tailed t-test for paired samples. Statistical significance was determined at the $P < 0.05$ level.

RESULTS

By comparison of the plantar pressure distribution between deformed group (Figure. 1)and the control group, pressure distribution pattern showed significantly different (Figure. 2). The forefoot area, especially the other toes region of the deformed group was significantly less than the value in control group. Particularly, the fifth toe region showed no contact force.

The peak pressure of the deformed group (Figure. 3) compared with the control group found significantly difference in heel, hallux and 2-5 toe regions. It should be noted that in 2-5 toe area, the peak pressure of the deformed group also significantly less than the control group, the pressure value of the 2-5 toes region only appeared one third of the value shown in the control group. While the peak pressure value in hallux was found 32% higher than it appeared in the control group.

For pressure-time integral value, lateral forefoot, medial forefoot, hallux and the 2-5 toes areas showed a significant difference between two groups (Figure. 4). The result compared with peak pressure showed a different pattern, mainly in the heel, lateral forefoot and medial forefoot areas. For heel region, the pressure-time integral value wasn't found significantly difference, but lateral forefoot and medial forefoot which weren't shown in peak pressure value.
Fifth toe deformed group showed slight medial side move tendency from Center of Pressure line. In the toe area, the percentage of contact time in toe deformation group was significantly larger than this in control group. It need to focus that, in the toe region, toe deformed group's Center of Pressure line has been completely shifted to the hallux, while the control group normally between the first and second toes.

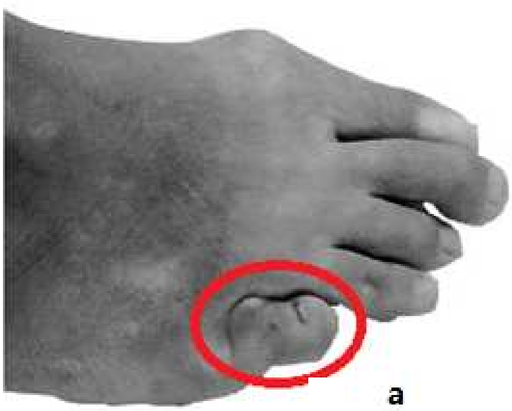

Figure.1 The illustration of the fifth toe deformation

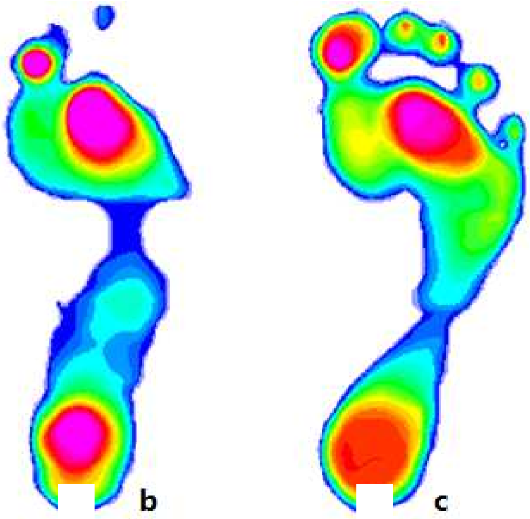

Figure.2Plantar pressure distribution between toe deformation group(left) and controls(right)
*(*means significantly difference exist)*

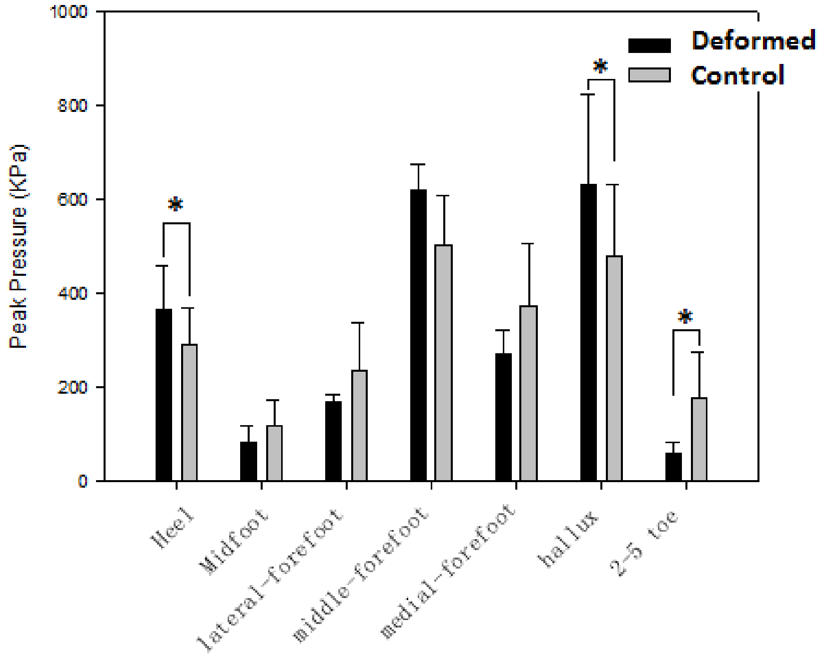

Figure 3.Peak pressure comparison between toe deformation group and controls
*(*means significantly difference exist)*

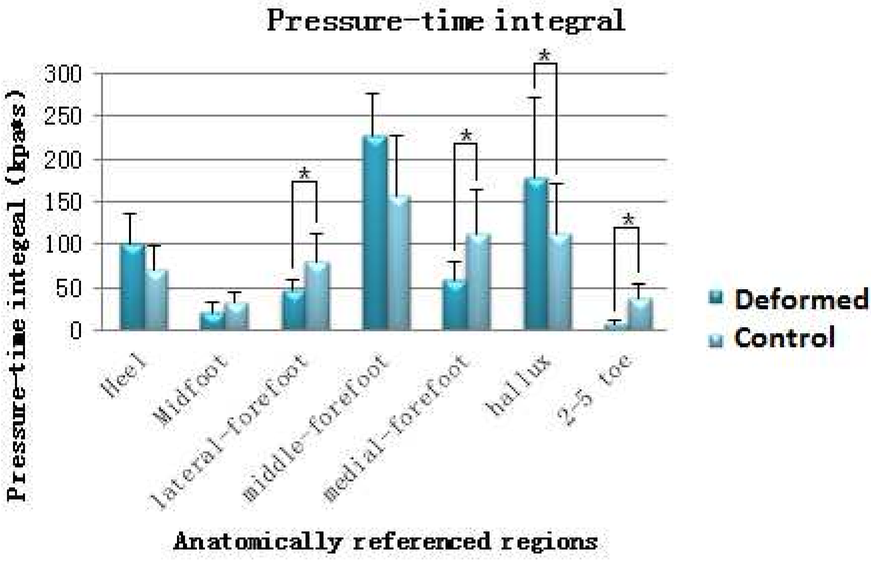

Figure 4.Pressure-time integral comparison between toe deformation group and controls
*(*means significantly difference exist)*

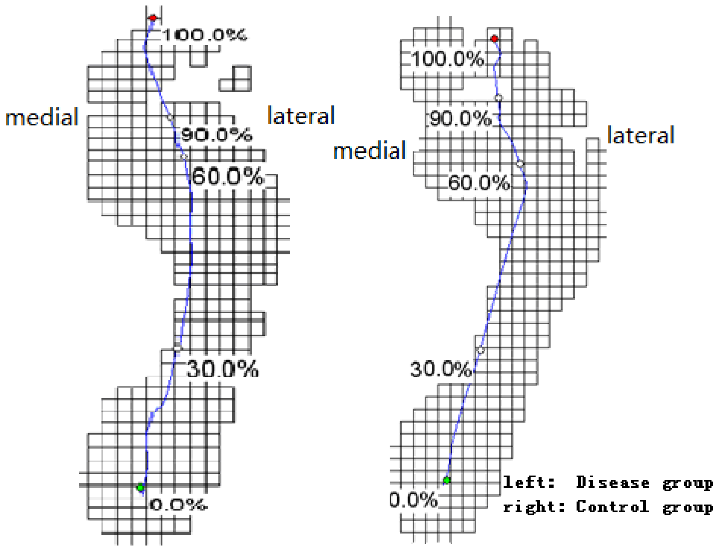

Figure 5.Center of pressure line variety during walking in two groups

DISCUSSION

Importance of biomechanical study of toe deformity in diabetic patients has been demonstrated by previous studies [12, 13]. The results in this study clearly showed that the fifth toe deformity is associated with significantly changed index such as peak pressures, pressure-time integrals, and Center of Pressure line at the plantar surface. These founding reflected that the fifth toe deformed caused some impact on the patient's gait characteristics.

Kinematics measurement methods are widely employed to study foot function, the mechanical pathogenesis of foot disease and as a diagnostic and outcome measurement tool for many treatment interventions [14]. It showed significantly impact decreased in the lateral of forefoot and 2-5 toes regions in toe deformation group, because of the fifth toe has demonstrated significant deformity that is unable to withstand any loading. The contact area in the toe deformation group is also significantly less than the control group, which is similar with the previous studies [15]. The main function of the toes in gait is to contact the surface and exert sufficient pressure to obtain a fixed point from which the body can be propelled [16]. Due to the deformation group's the fifth toe function has seriously damaged, it made the hallux region undertake more impact to reduce the burden which lateral toes shall bear. Highly increased pressure under hallux shall be taken seriously, because this phenomenon would cause a serious of symptoms such as hallux valgus, plantar aponeurosis pain, etc [17, 18].

Clinically, the importance of studying the biomechanics of toe deformity in diabetic patients has been demonstrated by several studies which showed that foot structural abnormality is a significant independent predictor of plantar ulceration in these subjects [12, 13]. Hallux demonstrated significantly greater suggest that diabetic subjects with the fifth toe deformity are at increased risk for ulcer development at this part. What's worse, the hallux region is also the most common sites for plantar ulcers to occur in the neuropathic foot [19]. Combining with Center of Pressure line during gait cycle, we could found that the toe-off stage is significantly different in two groups (Figure 5),which may be an important factor contributing to the high loading of hallux. As the contact area of toes reduced in the deformation subjects, they must rely on the hallux to bear more loading for keeping the body in stability during toe-off stage.

CONCLUSION

This study found that hallux region is the most sensitive area in the fifth toe deformity group. One of the contributions of this study is helping diabetic patients or doctors fundamentally understand the consequence of the diabetics with the fifth toe abnormalities. Also it shall pay attention to changes of pressure distribution, center of pressure line as this caused the hallux region force and contact time increasing. It is necessary to reduce the risks in this region through some implements like functional footwear, making the patient's plantar pressure distribution in normalization.

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