The Role of Total Contact Orthosis on Plantar Pressure Distribution during Stair Walking in People with Diabetes

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Abstract

Abnormal plantar pressures during ascending and descending stairs cause an adverse effect on the plantar load distribution in people with diabetic foot complications. However, limited data are available to examine the plantar peak pressure during stair ascending and descending in diabetic people. The aims of this study were: to assess the differences regarding in-shoe plantar pressure in patients with diabetes during stair ascending and descending and to assess the effects of TCO in plantar pressure distribution. Subjects without conditions affecting their ability to perform stair ascending and descending activity were recruited. Each participant ascended and descended (10 steps 3 rounds). Peak plantar pressure was measured using Pedar X insole. The regional plantar pressure from the hallux, metatarsal 1-5, mid foot and heel was also analyzed. During stair ascending, the metatarsal heads and the hallux had higher peak plantar pressure compared to the stair descending. On the contrary, during the stair descending the hind foot had higher peak plantar pressure compared to stair ascending without TCO. The peak plantar pressure while using TCO was reduced dramatically compared to the shoe only condition. The plantar pressure distribution pattern was different for both stair ascending and descending activity. The TCO can effectively reduce the peak plantar pressure during stair ascending and stair descending.

Keywords*:* Diabetic feet; Stair walking; Total contact orthosis; Plantar pressure.

1. Introduction

Diabetic foot ulcerations and amputations are fearful complications related to diabetes and it has an adverse direct effect on the individual and also society [1]. The diabetic feet are at increased risk of ulceration because of the effects of diabetic pheripheral neuropathy. Diabetic foot ulceration is the results of several factors including poor sensation, biomechanical pressure and load trauma. An appropriate footwear and understanding of specific ambulatory activities may be useful for the prevention of plantar foot ulcers [2].

To date, most research works emphasis primarily on level walking, other activities such as stair ascending and descending which has yet to be studied in terms of plantar pressure distribution [3]. Increased range of motion is compulsory in order to perform the activity. It is predictable that callus formation under metatarsal heads interrupts the plantar pressure distribution. In clinical practice, clinicians try to redistribute the pressure and provide relief to the pressure sensitive regions where the chances of ulcerations are more, reduced through total contact orthosis (TCO) [4, 5]. The prescription of TCO is based on the hypothesis that excessive pressure lead to callus formation and ulceration under bony prominences.

In-shoe plantar pressure measuring system is being used frequently to obtain more precise information [6, 7]. Understanding of plantar pressure distribution and effectiveness of total contact orthosis in diabetic feet population will improve the clinical management of diabetic patients with foot complications. However, the relationship between plantar pressure and callus formation during stair walking is still unclear. The objectives of this study were to assess the differences regarding in-shoe plantar pressure in patients with diabetic feet during stair ascending and descending and to assess the effects of TCO in plantar pressure distribution

2. Methods

2.1 Subjects

Sixteen subjects were recruited from the primary care unit (PCU) at Songklanagarind hospital. The experimental protocol was approved by the human research ethical committee of faculty of medicine, Prince of Songkla University. Inclusion criteria were diabetes type II, age between 40 and 60 years, having callus or forefoot deformities as this group of subjects is

most at risk of foot ulceration, unable to feel 5.07 Semmes-Weinstein monofilament and able to walk independently without supportive devices. Subjects with ulcers or Charcot's feet or any kind of amputations were excluded from the study. The patients were supplied with TCO and shoes. All subjects were informed about protocol and signed the informed consent form before participating in the study. Demographic details are shown in Table 1.

Table 1 Demographic data of subjects

Parameters	Mean	SD
No. of subjects	16 (8 Males, 8 Females)	
Age (year)	58	9
Height (cm)	157	8
Weight (kg)	74	14

2.2 Insole Preparation

The fabrication of TCO was done by certified prosthetist and orthotist in order to diminish the variation while modification. Foam impression was taken with the patient sitting with knee 90 degrees, neutral talus bone and controlled calcaneus bone without disturbing the medial arch. Positive molds were modified according to the blue ink footprints. The TCO were fabricated using individual positive plaster molds as shown in based on the foam impression taken at the time of casting as in Fig. 1. The TCO were adjusted and fitted into the patient's shoes and then patients were asked for discomfort feedback. All shoes had same heel height, to reduce the effect of the shoes on plantar pressure measurement as shown in Fig. 2.

Fig. 1 Fitted total contact orthosis.

Fig. 2 Sports shoe with heel height.

2.3 Plantar pressure Measurements

After the patients were fitted with TCO, the dynamic in-shoe plantar pressure measurement was recorded without and with TCO using Pedar® system (Novel GmbH, Munich, Germany) as shown in Fig. 3 (a), the insoles were placed between the socks and shoes. The Pedar® system has various sizes of flexible insoles with 99 sensors within each insole. The data acquisition rate was 100 Hz during the activity. The accuracy of Pedar® system insole measured with a resolution of 5 kPa that is the pressure range from 30 to 1200 kPa. The participants ascended and descended 10 steps (step height 17.5cm and 20.9 cm deep) for 3 rounds at self-selected speed with and without TCO as in Fig. 3 (b).

(a) (b)

Fig. 3 (a) Pedar® insoles fitted while participant wearing shoes, (b) Stair walking with and without TCO.

2.4 Data processing

Pedar Expert® software version 19.3.30 (Novel GmbH, Munich, Germany) was used to select consecutive 3 gait cycles from the raw data

file. Four foot regions were focused as hind foot, mid-foot, forefoot and toes using Pedar Expert®.

2.5 Statistical Analysis

The descriptive statistics of plantar pressure was expressed as mean and standard deviations. Statistical analysis for plantar pressure was done using Prism 5.0 for Windows (GraphPad Software, San Diego, USA). A paired t-test was used to assess parameters derived from the plantar pressure measurements. The statistical significance of the test was set at $p<0.05$.

3. Results

The peak plantar pressure values during stair ascending and descending were significantly different between with and without TCO. With TCO condition, peak pressure was significantly affected in the toes and forefoot regions of the foot. There were significant difference of peak plantar pressure without TCO during stair ascending in the toes (216.71±7.03 kPa) and forefoot (275.15±2.81) while using TCO the plantar pressure reduction was significant at toes (158.35±7.89 kPa) and forefoot (218.59±2.34 kPa) regions of the foot as shown in Fig. 4.

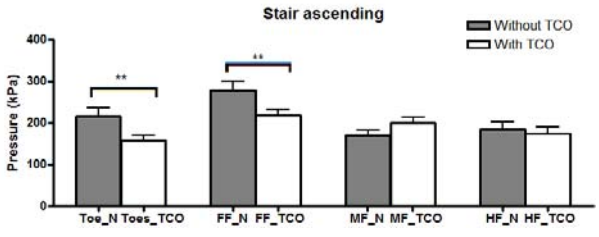

Fig. 4 The peak plantar pressure during stair ascending in two conditions of four plantar areas: toes (Toe), forefoot (FF), mid-foot (MF) and hind foot (HF). Significances between groups are displayed with ** ($p<0.01$). Values represent mean and standard error of mean (S.E.M.)

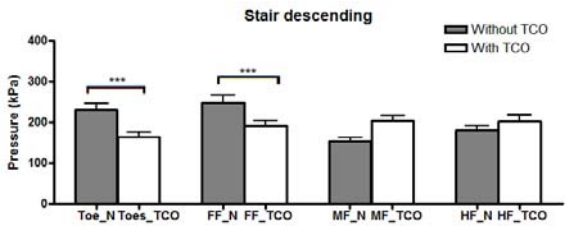

Fig. 5 The peak plantar pressure during stair descending in two conditions of four plantar areas: toes (Toe), forefoot (FF), mid-foot (MF) and hind foot (HF). Significances between groups are displayed with *** ($p< 0.001$). Values represent mean and standard error of mean (S.E.M.)

Furthermore, during stair descending without TCO the peak plantar pressure was higher at toes (229.53±19.06 kPa) and forefoot (248.52±4.14 kPa) whereas the significant differences in TCO condition were observed at toes (164.45±5.07 kPa) and forefoot (191.95±0.23 kPa) as shown in Fig. 5. However no significant differences were noticed in the mid-foot and the hind foot while using TCO.

4. Discussion

The most important findings of our study proved that TCO tend to reduce the plantar pressure by redistribution of pressure. The redistribution of plantar pressure while using TCO has an effect on the forefoot region which is in agreement with the previous results [7, 8]. The toes and forefoot regions of the foot have had higher plantar pressure during stair descending than stair ascending which was effectively reduced while using TCO [9]. The application of medial arch support TCO have widely used in order to maximize the surface area. The peak plantar pressure results showed that the TCO elevate the longitudinal arch of the foot hence increasing the plantar pressure at the mid-foot region and prevent it from the collapse of the medial arch of foot. Further studies are necessary to investigate the lateral and medial regions of the foot in order to design the effective TCO for patients who have diabetic feet.

5. Conclusion

Patients with diabetic feet who are at high risk for developing ulcers, total contact orthosis in a combination with stable shoes resulted in lower pressure at the forefoot and toe regions of the foot.

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