The Immediate Effect of the Toe only Rocker on Walking Parameters in the Patients with Type 2 Diabetes

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Abstract

Introduction: The prevention of foot ulcer and the improvement of gait pattern in the diabetic patients are crucial to understand the lower limbs kinematics. Various kinds of rockers can be used in shoes to reduce the forces applied on the plantar surfaces in patients with diabetic foot. The aim of this study was to investigate the kinematic parameters of gait using toe-only rocker shoes in patients with diabetic foot. **Methods and Materials:** Forty type 2 diabetic patients (22 females; mean age 58.2) were recruited for participation in this study. Examination of the subject's gait in this study was based on two walking conditions including standard shoes and shoes with toe-only rocker. A three-dimensional gait analyses was conducted to assess the kinematic parameters. For comparison the two test conditions, a paired t-test was utilized. **Results:** With the application of shoes with toe-only rocker, there was no significant differences in the walking speed improvement compared with standard shoe(P=0.260), However, the step length and cadence (P<0.001) were significantly increased when walking with toe-only rocker shoe compared with standard shoe. The range of motion of all three lower limb joints (ankle, knee, and hip) was significantly decreased using toe-only rocker shoe (P<0.05). **Conclusion:** The present study demonstrated a significant increase in the cadence and step length and a significant reduction in range of motion of lower limb joints during walking using toe-only rocker shoes compared with standard shoes in diabetic patients. Based on the results of this study, it seems that toe-only rocker can improve the gait pattern of people with diabetes. More study with long term follow-up is needed.

Keywords: Diabetic Foot, Kinematic, Gait, Toe-only Rocker, Shoe

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Introduction

Diabetes mellitus is one of the most common non-communicable diseases (1). According to statistics, in 2000, over 170 million people worldwide were infected with the disease. It is also expected that by 2030 the number of people with the disease will increase to about 360 million worldwide (2). Limb amputation in diabetic individuals is about 15 times more than normal individuals (3) Peripheral neuropathy is the most common risk factor for ulcers in diabetic patients (4). Many diabetics suffer from lower limb ulcers, which have become one of the most important concerns for people with peripheral diabetic neuropathy (5, 6). Diabetic foot is the most common, costly and severe complications of diabetes (3). Due to the sensory feedback reduction, these patients are unable to respond appropriately and in a timely manner to further improve or prevent injury during skin damage. For this reason, diabetic patients are at high risk for scarring, especially in the area below the metatarsals (7).

Since the gait pattern is disturbed, control over walking is decreased in diabetic than healthy people (8-10). These patients usually change their gait pattern in different environments (11). According a study, these patients took an average of 7,816 steps a day, while patients with a history of foot ulcers took an average of 5,454 steps per day (12, 13). A study examined the range of motion (ROM) of the ankle joint in people with diabetes, and the results showed more ROM of the ankle joint in people with diabetes compared with healthy people (14). Sacco *et al.* showed the pressure in the mid-foot and fore-foot regions was significantly increased due to decrease the ankle ROM during stance phase (15). Studies have also shown that patients with

Table 1.Patient demographic information

Variable	Mean (SD)
Age (year)	58.2 (8.07)
Weight (kg)	75.48 (11.62)
Height (cm)	170.87 (8.79)
Gender (female)	56%

Table 2. The comparison of inter- group (standard shoes with toe-only rocker shoes) of kinematic parameters [Mean (SD)]

Parameters		Standard shoe	Toe-only rocker shoe	Mean differences	*P*-value
Speed (m/s)		0.96(0.14)	0.98 (0.16)	0.2 (0.07)	0.260
Cadence (stride/min)		44.45(5.73)	48.2 (7.04)	3.75 (6.1)	0.000*
Step length (m)		118.2(11.93)	128.56 (11.55)	10.3 (54.46)	0.000*
Range of motion (deg)	**Hip**	45.06 (5.93)	41.32 (6.15)	-3.74 (5.93)	0.000*
	Knee	54.29 (13.15)	48.73 (12.4)	-5.56 (4.99)	0.000*
	Ankle	20.26 (5.22)	18.31 (4.37)	-1.95 (3.42)	0.012 **

***P< 0.05,*=P<0.001. Negative values for range of motion show joints plantar flexion / flexion*

diabetic neuropathy generally have a shorter step length than healthy people (16, 17). Therefore, diabetic patients usually walk slower with a short step length to reduce foot pressure on the heel and toe (18).

Different types of orthotic treatments have been used for diabetic individuals to reduce loads applied on the foot. Medical shoes with rocker are the most common orthotic intervention used for the purpose of transfer the force from some parts of the foots to other during walking. Generally, to remove the weight from a part of the sole of the foot, the head of the rocker should be placed behind that point. A prospective clinical trial have revealed that therapeutic footwear with rocker can decrease the incidence of foot ulcers (19). Rockers in the front of the shoe can reduce the pressure on the metatarsal head and facilitates the transition from the mid stance to the late stance, thereby help to having better toe off (20, 21). Therefore, rockers could improve gait pattern which is alter as a result of diabetic.

Considering huge costs and the need to normal distributed pressure on the diabetic foot (to prevent its consequences), it seems necessary to use a therapeutic device to improve the gait of these people. In addition, diabetes has a high psychological injury, which reduces the quality of life in these people (22). Also, according to the literature, most studies have been performed on healthy individuals(14, 15, 23), and due to the difference in the walking status of diabetics compared to healthy individuals (15), the results of these studies cannot be generalized to diabetics. Moreover, due to the lack of proper balance in diabetic patients with neuropathy (10), some of the rockers used in the above studies such as heel to toe rocker cannot be utilized for these people. Therefore, the aim of this study was to investigate the gait of diabetic patients using toe-only rocker shoes.

Material and Methods

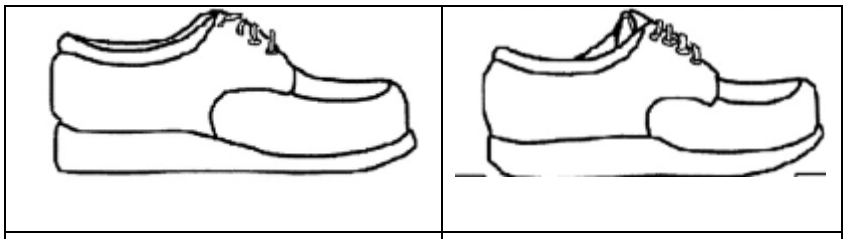
Participants

Forty diabetic patients (22 females; mean age 58.2; Table 1) were recruited for participation in this quasi-experimental study. The Research Ethical Committee of the social welfare and Rehabilitation University approved the study. Before the start of the study, patients were informed about all of the study procedures and filled out the consent form.

Inclusion criteria were people with type 2 diabetes, no history of bone surgery in the lower limbs, absence of neurological disorders or any pathology in the ankle/foot complex (except neuropathy) which causes a change in gait pattern, lack of length difference in the lower limbs, and absence of skeletal abnormalities in the ankle/foot complex. Persons with a history of musculoskeletal disease, injury to the lower limb recently, use of foot orthoses and surgery on the lower limbs, an abnormal gait pattern characterized by the presence of abnormalities that are visible to the eyes while walking including: lateral bending, back-to-back or excessive lordosis, forward torso flexion at the beginning of the walking cycle, lower limb length difference, hyper flexion or hyperextension of the knee, were excluded from this study (24).

Intervention

The standard shoes condition consisted of a pair of standard Oxford-type shoe (Gadean footwear, Perth, Australia). To prepared shoes with the toe rocker, the standard shoe was modified with the toe-only rocker as follow. The toe-only rocker had two anterior and posterior arches that form the anterior arch with a 7-degree angle horizon line, and the anterior arch has a greater radius than the posterior arch. The head of this



Standard shoe	Shoe with toe-only rocker

Figure 1. The interventions used in the study

rocker was 65% of the shoe length which made an angle of 30 degrees with the ground (25). The rocker was made of rubber (ethyl vanilla acetate) with a hardness of 30-40 and its thickness was 30 mm(24) (Figure 1).

Data Collection

After preparation of shoes for each subject, participants were asked to walk with the standard shoe and toe-only rocker shoe for 10 to 20 minutes to get used to it. Test conditions (shoes with or without toe-only rocker) were selected randomly. The subjects were asked to walk at their self-selected speed and continue walking until the examiner announces. Meanwhile, the data received by the infrared cameras were recorded by the computer connected to the cameras. Examination of the subject's gait in this study was based on the following conditions: standard shoes and toe-only rocker shoes.

A three-dimensional gait analyses was conducted at the gait laboratory within the University of Social Welfare and Rehabilitation for each patient under each of the two conditions. At the beginning, the volunteer subject was explained all the steps of the test and sufficient assurance were given that the test was safe. To record information about the movement of these people, the three-dimensional movement analysis system of Vicon UK model, Oxford metrics with four infrared cameras with a frequency of 100 Hz was used to collect walking information. The device was calibrated before receiving the information. Infrared sensors should be placed on prominent anatomical points to capture images of the movement of the whole body using Vicon. A series of 16 retro reflective markers (14 mm diameter) were employed. The markers were placed at the bilateral anterior superior iliac spines, the posterior superior iliac spine (PSIS), lateral epicondyle of the knee, lateral thigh, lateral tibia, lateral malleolus, second metatarsal head, and calcaneus(26).

All extracted data from NEXUS software were analyzed. Stride length was obtained using the marker data on the heel; velocity was obtained by assessing the mean value of the coordinates of the two markers on the two PSIS, and dividing their displacement rate per unit time (s). By counting the number of steps per unit of time (min), a cadence value was acquired. Maximum ROM of ankle, knee, and hip was obtained by a simple subtraction of the minimum angle from the maximum angle during a given cycle. All gait variables were averaged across three trials (27).

Statistical Analysis

The normality of the dependent variables was confirmed using the Shapiro-Wilk test. For comparison the two test condition, a paired t-test was used, with a level of significance of P=0.05.

Results

A total of 40 people with diabetes were invited to be assessed for eligibility. The clinical characteristics of the recruited patients in the study are shown in Table 1.

Based on the results, with the application of shoes with toe-only rocker, walking speed improved compared with standard shoes, but this difference was not statistically significant (P=0.260). However, the step length and cadence were significantly increased when walking with toe-only rocker shoes in comparison of standard shoes by 10 % and 8.5 %, respectively (P<0.05) (Table 2).

Regarding ROM parameter in sagittal plane, the results showed the ROMs of the ankle, knee, and hip joints were significantly reduced when walking with rocker shoes compared with standard shoes (Table 2).

Discussions

The protocol for this study was designed to assess the effect of toe-only rocker shoes on kinematic parameters in individuals with type 2 diabetes to answer the question whether the use of toe-only rocker influences the kinematic of lower-extremity joints.

Our analysis demonstrated the walking speed parameter was the same in both conditions (standard shoes or toe-only rocker shoes). The results of a study by Arazpour *at al.*, which examined the effect of heel to toe-only rocker on healthy individuals, showed that there was no significant difference in walking speed compared to standard shoes (28). Two studies which evaluated the effect of different types of rockers, reported no difference in walking speed by types of rockers in healthy people (23, 26). Also Bogart's study (29), which examined the effects of toe-only rocker on the gait of healthy people, showed no difference of walking speed. In other studies, which assessed the effect of double rocker (23), negative heel rocker (26) and toe-only rocker (30), the walking speed of healthy people did not change, which is in consistent with our study. However, in mentioned studies cadence parameter was significantly increased with rocker shoe that is also in the line of present study results. The reason for the increase of cadence can be considered the facilitation of toe lifting by toe-only rocker. Diabetic patients use a shuffling gait pattern to reduce the foot pressure, which means increasing the average time of the mid-stance**,** this is accompanied by a decrease in walking speed and foot pressure (31, 32). Therefore, patients with diabetic neuropathy walk slower with a short step length to reduce foot pressure on the heel and toe (18). However, a potential limitation of this study was the immediate effect of toe-only rocker on speed parameter. Since patients need more time for adaptation to rocker, further long-term researches are needed in this regards.

The present study results demonstrated a significant increase of step length (10 %) by toe-only rocker. The results of a study, which examined the effects of negative heel rocker on healthy people, showed that the step length was reduced (26). The reasons for this difference could be due to the difference in the type of rockers and most importantly reason could be due to difference in the walking patterns between healthy and diabetic people. In healthy people by toe-only rocker, the normal step length was reduced due to the change in weight transfer from heel and the middle of the foot to toe, and the reduction of dorsi flexor activity with the negative heel rocker, thereby the toe lift was increased (26). Decreased heel height in negative heel rocker can be another reason for the step length reduction. In Bogart's study with toe-only rocker, also, step length was reduced (14). Unlike Bogart's study, the toe-only rocker increased the step length parameter of the diabetic foot in the present study. Since the step length in people with diabetes due to an imbalance during walking is usually lesser than normal people (26), the cradle-shaped pattern embedded in the front of the shoe reduces the pressure on the metatarsal head, facilitates the transition from the midstance to the late stance phase of gait, and lifts the toes from the ground (30).

In the present study, the ROM of all three lower limb joints including hip, knee and ankle was significantly decreased using toe-only rocker in shoes compared with the standard shoe. In Longs' study, the doubled rocker decreased the knee and ankle ROM in the sagittal plate. In negative heels rocker, also, ankle ROM was reduced in healthy people (30). Moreover, in VanBogart's study, which looked at the gait of healthy people, the ROM of all three lower limb joints on the sagittal plate was reduced(14).In justifying the results of the present study, it can be said that toe-only rocker needs to move the lower limb joints due to the facilitation of the transition from the mid stance to the late stance phase and the lifting of the toes. Thus, it reduces the ROM of hip, knee and ankle joints.

One of the limitations of the present study was exanimating just one type of rockers and without follow-up period. The lack of measurements of energy consumption, muscle activity and kinetics was another limitation of the present study. It is suggested that a study is conducted with a follow-up time and with different types of rockers, so that more complete and comprehensive results can be expressed in this regard and this issue can be examined more accurately and meticulously.

Conclusion:

The present study demonstrated a significant increase in the cadence and step length and a significant reduction in range of motion of lower limb joints during walking using toe-only rocker shoes compared with standard shoes in diabetic patients. Based on the results of this study, it seems that toe-only rocker can improve the gait pattern of people with diabetes. More study with long term follow-up is needed.

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