Iranian Rehabilitation Journal, Vol. 13, Issue 1, Spring 2015

Original Article

The Effect of Rocker Shoe on the Ground Reaction Force Parameters in Patients with Rheumatoid Arthritis

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Objectives: Foot and ankle problems are common complications in rheumatoid arthritis disease. Gait pattern such as normal foot and ankle rocker is impaired in patients with rheumatoid arthritis. Rocker sole as an external shoe modification is commonly prescribed in this pathology. The aim of this study was to investigate the effect of rocker shoe on vertical ground reaction force parameters during walking in patients with rheumatoid arthritis.

Methods: Sixteen female participants with rheumatoid arthritis were recruited in this study. All patients were prepared with a pair of high-top, heel-to-toe rocker shoe and were asked to wear the shoes for one month. Ground reaction force parameters including peak forces and peak force times were evaluated in the first session, and after seven days and thirty days follow up were carried on.

Results: First maximal vertical force was significantly increased with rocker shoe compared to barefoot after 7 days follow up. Walking with rocker shoe reduced the minimal vertical force after 7 days. The second maximal vertical force showed to be statistically lower with rocker shoe than barefoot after 7 and 30 days. Furthermore, stance time decreased with rocker shoe after one month.

Discussion: Results of this study revealed that vertical ground reaction force parameters changed in rheumatoid arthritis patients with heel-to-toe rocker shoe, both immediately and after one month follow up. This might suggest the effectiveness of rocker shoes in improving gait in rheumatoid arthritis patients.

Keywords: Rheumatoid arthritis; Rocker shoe; Gait; Ground reaction force

Submitted: 01 January 2015
Accepted: 05 February 2015

Introduction

Foot and ankle involvement is a common complication in rheumatoid arthritis disease (1). A rheumatoid foot is often affected by deformities such as hind foot valgus (2), metatarsophalangeal joint subluxation, forefoot hallux valgus and claw and hammer toe (3). Moreover, limited ankle and subtalar range of motion, flattened medial arch and muscle weakness are commonly reported in rheumatoid arthritis (4,5). These involvements can cause pain, disability and activity limitation as well as functional impairment such as altered gait pattern in rheumatoid arthritis patients (4-8). Gait analysis studies have demonstrated that normal gait is disrupted in rheumatoid Arthritis. Patients with rheumatoid arthritis walk slower with prolonged stance and double-support time and decreased step length (9-11). Moreover, it has been reported that the normal rocker function of ankle and forefoot is impaired (4,7). For example delayed and reduced heel rise, decreased ankle plantar flexion in terminal stance, reduction in ankle peak power and moment and delayed progression of center of pressure are reported in rheumatoid arthritis gait (4-6,9,10). Additionally, in rheumatoid arthritis patients the normal loading pattern under the foot is changed to

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compensate for structural impairment. The peaks of vertical Ground Reaction Force (GRF), which occur during the loading response and terminal stance, are lower in rheumatoid arthritis gait compared to the normal population (7,10,12).

In rheumatoid arthritis management, foot care goals are reliving pain, improving activity and maintaining function (13). Conservative treatments such as shoe modifications and orthotic devices are suggested to achieve these goals (14-17). Rocker sole, as one of the most commonly prescribed external shoe modifications, is recommended for rheumatoid arthritis patients (14,16-20). The biomechanical reason of adding a rocker to the shoe sole is to control foot and ankle motion by creating a rigid platform which rolls the foot from heel to toe-off and leads to a normal heel-to-toe motion (18,21). Walking with rocker sole reduces the need for ankle motion by facilitating the forward advancement of the tibia which helps the leg propulsion at toe-off and therefore changes the muscle activity and vertical GRF loading pattern(18,22-24). Previous studies have demonstrated that rocker sole shoes are effective for reducing foot pain, improving foot function and activity limitation in rheumatoid arthritis condition (14,15,19). Although rocker sole shoe is a suggested intervention for rheumatoid Arthritis, there are limited gait analysis studies supporting its application. Gait parameters such as magnitude and timing of vertical GRF are altered in rheumatoid arthritis patients (7,10,12).

The purpose of this study was to investigate the effect of rocker sole on peak and timing of vertical GRF during walking in rheumatoid arthritis patients. It was hypothesized that rocker sole would produce changes in GRF parameters in patients with rheumatoid arthritis after 7 and 30 days of follow up.

Methods

Sixteen female rheumatoid arthritis patients with the mean age of 46.5 ± 8.25 years, weight of 67.0 ±9.73 kg and disease duration of 8.2 ± 7.4 years were recruited in this study. The diagnosis of rheumatoid arthritis was performed by an experienced rheumatologist, based on the American College of Rheumatology criteria (25). Further inclusion criteria were having non-active disease that defined as a disease activity score 28 (DAS 28) of <2.6 (3), rheumatoid arthritis history of more than one year (26), age between 20 and 60 years (3, 27), independent walking ability and self-reported bilateral foot and/or ankle pain (14,27). The exclusion criteria consisted of skin ulceration or dermatitis (27), central or peripheral nervous system disorders, previous lower limb surgery, rigid pes-planeus or pes-cavus, ankle sprain or strain three months before the study, intra-articular steroid injection in the last three weeks prior to the experiment or currently using orthopaedic orthoses or shoes (14,27). The study was approved by the ethics committee of Faculty of Rehabilitation Sciences, Iran University of Medical Sciences (IUMS), Tehran, Iran; and written informed consent was obtained from each patient.

All patients were provided with a pair of extra-depth, high-top shoe modified with a heel-to-toe rocker and velcro closures (17). Each pair of rocker sole was individually fitted by an experienced orthotics based on the standardized rocker design and subject specific measures (Figure 1). The apex of heel rocker was positioned anterior to the medial malleolus and had an angle of 15º. The toe rocker apex was centered 63% of the shoe length and angled at 25º (14,21,28). The rocker consisted of two layers of 25mm thick ethylene vinyl acetate in midsole and 5-mm thick rubber with shore-A 50-60 hardness in outsole (14,21).

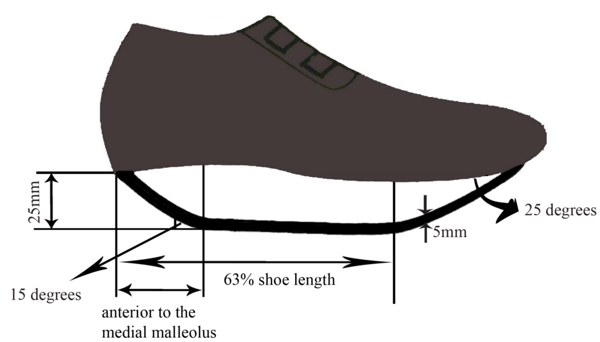
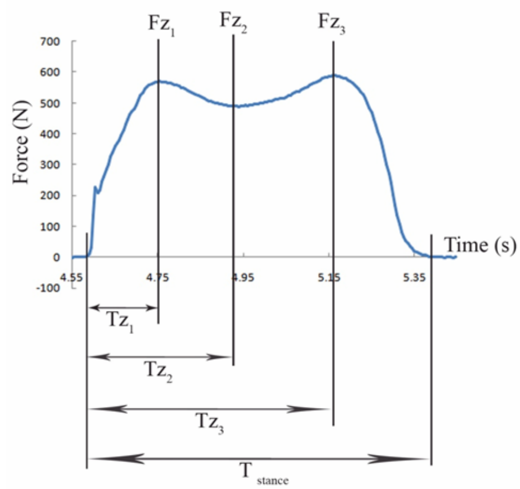


Fig 1. Structure of rocker shoe

Analyses were carried out in a gait laboratory equipped with two force plates (Bertec 4060-10force platform, USA). Data were collected at the sampling rate of 200 Hz. All analyses were performed in three evaluation sessions including the first visit, after 7-days and 30-days follow up. In the first evaluation session and prior to the data collection, each patient was custom fabricated with a pair of rocker sole shoe and allowed to get accommodated to the shoe for 5 minutes (14). Afterwards, subjects were asked to walk at a self-selected gait speed across a 9 meter walkway in two conditions including bare foot and wearing the rocker sole shoe with a randomized order. At least three complete trials for each condition were captured, in which the feet were stepped entirely on the force plates. After completing the first evaluation session, the participants were asked to wear rocker sole shoes for one month. The same testing protocol was performed after 7 and 30 days intervals. all tests were performed in the afternoon in order to control the effects of early morning stiffness in rheumatoid arthritis gait (26).

The vertical GRFs were normalized to the body mass (N/kg) and the following variables were derived from the GRF graphs: first maximal vertical force (Fz_1), minimal vertical force (Fz_2) and the second maximal vertical force (Fz_3). Moreover, timing parameters including times of Fz_1 (Tz_1), Fz_2 (Tz_2) and Fz_3 (Tz_3) were defined from the graphs. Additionally, stance and double support times were computed for each condition (Figure 2).



• Fz_1: first maximal vertical force, Fz_2: minimal vertical force, Fz_3: second maximal vertical force, Tz_1: time to Fz_1, Tz_2: time to Fz_2, Tz_3: time to Fz_3 and Tstance: stance time.

Fig 2. Vertical ground reaction force parameters.

The data were then statistically analyzed using SPSS version 17 (SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was performed to assure the normal distribution of the data (P>0.05). A repeated measures analysis of variance (ANOVA) with Bonferroni-adjusted post hoc test was applied to compare the variables before and after the intervention. Alpha levels were set at 0.05 for all tests.

Results

The mean and Standard Deviation (SD) values of peak vertical GRF in barefoot and rocker shoe conditions at first (after 7 days) and second (after 30 days) follow up sessions are presented in the table 1. At 7 days follow up session, the FZ_1 with rocker shoe was significantly higher than barefoot condition (P=0.00), (Table 1). The $FZ_2$was decreased at the 7-days follow up compared to the first rocker shoe evaluation condition (P =0.00), (Table 1). After 7 and 30 days of follow up, the FZ_3 showed to be statistically lower with rocker shoes compared to barefoot conditions (P =0.01, P =0.00), (Table 1, Figure 3). No significant differences were found between other force variables (P >0.05), (Table 1).

Table 1. Mean (SD) values of peak vertical forces (N/kg) for barefoot and rocker shoe at three evaluation sessions.

variables	First evaluation		7-day follow-up		30-day follow-up	
	Bare foot	Rocker shoe	Bare foot	Rocker shoe	Bare foot	Rocker shoe
Fz_1	10.18(0.10)	10.53(0.20)	10.26(0.11)	10.66(0.14)[a]	10.24(0.11)	10.27(0.32)
Fz_2	8.65(0.11)	8.75(0.15)[b]	8.22(0.20)	8.38(0.15)[b]	8.66(0.13)	8.27(0.26)
Fz_3	10.48(0.92)	10.46(0.11)	10.60(0.11)	10.41(0.09)[a]	10.58(0.11)	10.32(0.07)[c]

SD: standard deviation.
[a] Mean difference is significant at the 0.05 level (Bonferroni adjusted) when comparing to 7-day follow-up barefoot.
[b] Mean difference is significant at the 0.05 level (Bonferroni adjusted) when comparing to first evaluation RS shoe.
[c] Mean difference is significant at the 0.05 level (Bonferroni adjusted) when comparing to30-day follow-up barefoot.

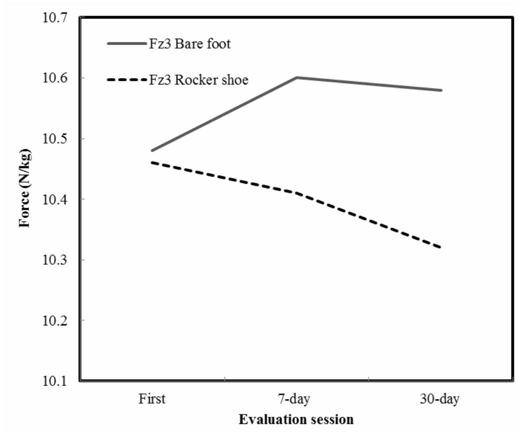


Fig 3. Mean values of Fz_3 during three evaluation sessions.

The mean and standard deviation (SD) values of GRF timing as well as stance time in barefoot and rocker shoe at the first evaluation and follow up sessions (after 7 and 30 days) are presented in the table 2. Comparing the barefoot conditions, statistical analyses indicated that the Tz_1 was lower in the 30-days follow up than the first evaluation (*P*=0.005). Additionally, the $Tz_1$was decreased with rocker shoe in the 7 and 30-days follow ups compared to the first evaluation rocker shoe (*P*=0.03, *P*=0.009) (Table 2). The Tz_3 was significantly higher with rocker shoe compare to barefoot condition at the first evaluation session (*P*=0.03). However, walking with rocker shoes resulted in a significant reduction in the Tz_3 after 7 and 30 days follow up when compared to the first evaluation rocker shoes (*P* =0.017, *P*=0.015) (Table 2). Statistical analyses demonstrated a lower barefoot stance time in the 7-days follow up session compared to the first session (*P*=0.03). Furthermore, comparison of rocker shoe stance time in 30 days follow up and first sessions suggested a significant decrease (*P*=0.005). Wearing the rocker shoe exhibited an increase in stance time in the first evaluation (*P*=0.006) (Table 2, Figure 4).

Table 2. Mean (SD) values of timing parameters (s) for barefoot and rocker shoe at three evaluation sessions.

variables	First evaluation		7-day follow-up		30-day follow-up	
	Bare foot	Rocker shoe	Bare foot	Rocker shoe	Bare foot	Rocker shoe
Tz_1	0.25(0.01)	0.28(0.02)	0.22(0.03)	0.22(0.01)[b]	0.20(0.01)[a]	0.17(0.02)[b]
Tz_2	0.39(0.01)	0.41(0.02)	0.37(0.03)	0.40(0.02)	0.31(0.04)	0.42(0.04)
Tz_3	0.61(0.02)	0.66(0.02)[a]	0.57(0.02)	0.59(0.01)[b]	0.57(0.03)	0.60(0.01)[b]
Stance time	0.86 (0.02)	0.96(0.05)	0.81(0.02)[a]	0.82(0.25)	0.81(0. 01)	0.81 (0.02)[b]
Double support time	0.26 (0.32)	0.30 (0.37)	0.18 (0.05)	0.26 (0.19)	0.17 (0.05)	0.18 (0.07)

SD: standard deviation.
[a] Mean difference is significant at the 0.05 level (Bonferroni adjusted) when comparing to first evaluation barefoot.
[b] Mean difference is significant at the 0.05 level (Bonferroni adjusted) when comparing to first evaluation RS shoe.

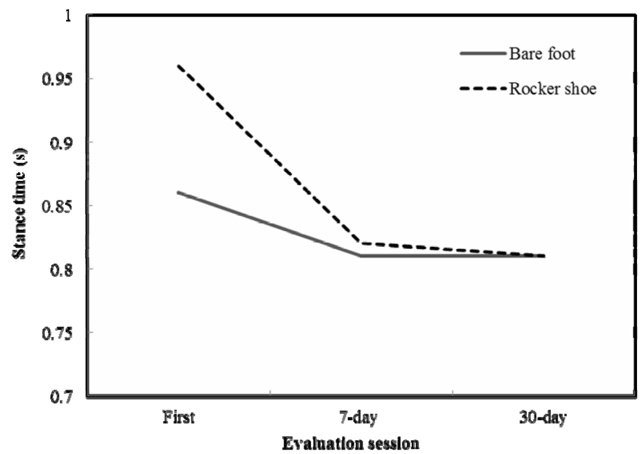


Fig 4. Mean values of Tstance during three evaluation sessions.

Discussion

The aim of the current study was to assess the effect of rocker shoe on peaks and timing of vertical ground reaction force during walking in rheumatoid arthritis patients. It has been demonstrated that patients with rheumatoid arthritis alter their normal gait pattern to compensate for foot pain or deformity (5,7,8).The findings of our study showed that the first peak of GRF increased with the rocker shoe compared to the barefoot. Similarly, Sloss reported an increase in the FZ_1 when wearing the orthosis (29). They attributed this increase to the used material, especially in the rheumatoid arthritis condition, where harder material is used to control pronation. In this study, the hard material (shore-A 50-60) was used in the fabrication of rocker shoe sole. This might have reduced the shock absorption at the heel strike and caused an increase in the FZ_1. Moreover, Cook et al. suggested that restriction in the knee flexion can increase the vertical GRF (30). In the current study, the heel apex of the rocker shoe was positioned anterior to the medial malleolus. This would produce a knee extensor moment, which may increase the FZ_1. Additionally, this may be the result of the rocker shoe mass as Masood (31) concluded that walking with unstable heavy shoe construction contributes to enhanced contact forces. The results showed a decline in the FZ_2 at the second and third evaluation sessions with the rocker shoe. This might be explained as if the patients got familiar with the shoe and consequently relied more on the shoe in the two last sessions. Furthermore, the findings exhibited that the use of rocker shoe effectively reduced the FZ_3 at the second and third evaluation sessions compared to the barefoot. The rheumatoid arthritis gait is characterized by the critical damage of the third rocker due to the diminished range of motion of the metatarsophalangeal joint, foot pain and deformities (3,7,12). This prompts a delay in the displacement of center of pressure (7,12), a late heel rise along with a reduction in the second vertical GRF peak (7,10,12). It can be said that the rocker shoe may result in the reduced forefoot range of motion, while simulating the dorsiflexion movement of the foot and facilitating the foot rocker function (21).Therefore, the reduction in the FZ_3 might confirm the function of the rocker shoe in promoting the third rocker and helping the toe off in the rheumatoid arthritis patients.

Previous studies displayed that foot pain and deformity were the predominant impairments in the rheumatoid arthritis (7).The prolonged timing of gait variables was also observed in these patients.(9-11) Our results revealed that the rocker shoe leads to a decline in the stance time along with the TZ_1 and TZ_3 during 30 days of follow up. This might be due to the pain relief, which was previously shown as an outcome of rocker shoe (14,19). It should be noted that the findings of this study are limited to a small sample (16 females) of the rheumatoid arthritis patients. Moreover, the effect of the rocker shoe was assessed only by analyzing the ground reaction force parameters and after 30 days of follow up. Therefore, a more comprehensive study with a longer follow up duration, comprising a larger population and both genders is recommended. It is also suggested to assess the kinetic and kinematic of lower limb joints to provide a better insight into the effect of such intervention.

Conclusion

In this study, the parameters of vertical ground reaction force were altered in the rheumatoid arthritis patients by the heel-to-toe rocker shoe immediately and after one month follow up. The reduced Fz_3 in all sessions showed that the rocker sole might facilitate toe off and therefore, it could be beneficial in gait improvement in the rheumatoid arthritis patients.

Acknowledgements

The authors would like to thank Mr. Haseli for the fabrication of rocker shoes. All the experimental procedures were conducted at RRC IUMS Biomechanics Lab.

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