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The Effects on Functional Balance in Hemiplegic Stroke Individuals Wearing an Ankle Foot Orthosis with Rocker Bottom Shoes

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ABSTRACT

Background: One of the disorders in stroke patients is asymmetrical posture, which leads to decreased movement and balance control. An ankle-foot orthosis (AFO) is the most common orthopedic device used in patients with post-stroke hemiplegia, and are often utilized with shoes. The purpose of this study was to investigate the effect, in stroke patients, of rocker bottom shoes on an AFO in the clinical assessments of balance compared to standard shoes on an AFO.
Methods: This quasi-experimental study involved 10 chronic stroke patients. The evaluated individuals were under four conditions using rocker bottom shoes and standard shoes coupled with a rigid AFO immediately, and after a 3-week adaptation. The walking speed was assessed using a 10-m walk test (10 MWT), and the clinical assessments of balance were evaluated using the Timed-Up and Go test (TUG) and the Functional Reach Test (FRT).
Results: The findings revealed that wearing rocker bottom shoes on the AFO significantly increased walking speed, the distance on the FRT, and reduced the TUG compared to wearing standard shoes on the AFO ($P<0.05$).
Conclusion: The study indicated that stroke patients showed an improvement in walking speed and functional balance when utilizing the AFOs with rocker bottom shoes. This outcome could be a possibility in application by doctors to prescribe this type of footwear for individuals who have had a stroke.

Introduction

Stroke is currently one of the causes of death in the world, and if patients survive, it leaves them with significant disabilities that greatly reduces their independence [1]. Obvious disabilities are commonly seen in 30% to 40% of these people [2]. Functional balance disorder is one of the most common problems in hemiplegic stroke patients [3]. The sufferer is heavily dependent on family and the community for active daily living, which imposes a great psychological and physical stress for these individuals [1]. Ankle-foot orthoses (AFOs) are the most common orthopedic devices used to restore the function of the foot-ankle complex and improve the balance and gait in hemiplegic stroke patients [4, 5].

Studies have shown that use of a passive AFO utilized as a daily-wear device can improve the results of functional tests [6]. Some researchers believe that AFOs improve the static balance by reducing the center of pressure oscillations or increasing the symmetry of weight bearing on both limbs [7, 8]. In addition, the effects of these AFOs on walking parameters have been observed in several studies, which lead to increase in walking speed, step length and walking symmetry [9-11].

These orthoses are often utilized with outdoor shoes to cross paths and streets. The rocker bottoms are of the most common external shoe modifications in order to improve rollover and weight transfer during walking [12]. Studies have shown that AFOs can improve functional performance in stroke patients [6], however,

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it is not yet clear what type of shoes should be used with these orthoses to have the greatest impact on mobility performance in such patients. Studies have demonstrated that the correction of orthoses with the toe-only rocker bottom footwear can have a positive effect on the walking ability of patients with disabilities caused by neurological disorders [13, 14]. To the best of our knowledge, no study has yet examined the effects on functional balance in hemiplegic stroke patients and rocker bottom shoes worn with an AFO. Thus, we hypothesized that wearing shoes with a toe-only rocker modification while using AFOs could improve walking ability, and as a result, the functional balance in hemiplegic patients would stabilize.

Since there is no mention in the literature that use of rocker bottom shoes has a positive effect on the performance of AFOs, the purpose of this study was to investigate the effect of rocker bottom shoes with AFOs on functional balance in hemiplegic stroke patients. Indeed, the results of this study may help clinicians to make a better decision in using these types of shoes with an AFO.

Methods

Participants

Ten hemiplegic stroke participated in this quasi-experimental study. The sample size was calculated by using G*power software based on mean and standard deviation of the Timed-Up and Go test (TUG) with 95% confidence interval and 80% power in a related article [15].

Inclusion criteria were a history of at least 6 months after stroke, a maximum spasticity of grade 2 for ankle plantar flexors based on the Modified Ashworth Scale, no involvement or difficulty in use of the opposite limb, and ability to walk independently with and without assistive devices. Exclusion criteria were a history of cardiovascular and pulmonary disease, fixed contractures in the ankle, thigh and knee, patients with serious knee hyperextension or hyperflexion, and claw toe. The Ethics Committee of the University of Social Welfare and Rehabilitation Sciences, Tehran, Iran; Ethics Code IR.USWR.REC.1398.021, approved of this study. We provided the participants with a written informed consent form prior to the start of the study.

Interventions

The fabricated custom-molded AFOs for each patient were based on casting where the person was sitting on a chair and the foot was in a relative weight bearing position. Since the shoes used in this study had a 1-cm heel, casting was performed with 1 cm of heel height, so that the AFOs would fit inside the footwear and the knee would not be affected. The next step was to provide the modification of a positive plaster cast, including reducing the pressure on the ankles, correcting the cast angle at the ankle area, and maintaining the standard alignment of the shin area. Then, the orthoses were prepared using 4-mm polypropylene sheets to be fitted on each patient's foot.

The trim lines were extended to 2.5 cm below the fibula head, to the head of the metatarsals, and to half of both malleoli (Figure 1).

Figure 1: Rigid ankle–foot orthosis (AFO)

A pair of standard shoes and a pair of rocker bottom shoes were provided for each person based on their foot size. The difference between two shoes was the design of their rocker bottom. Standard shoes were described by a slight rocker angle at both heel and toe areas used as the baseline shoes [16]. To fabricate the rocker bottom shoes, a rubber rocker bottom with standard rigidity (a shore of 30-40 for the middle part) was attached to the inferior section of the standard shoes. The apex of the rocker bottom shoes was at 65% (proximal to metatarsal head) of the footwear length from the heel with an angle of 15° (Figure 2). The total height of the rubber was 2 cm. To prevent slipping, a rough rubber (a shore of 50-60) with 2-mm thickness was attached to the sole of both types of footwear.

Data Collection Tools

Assessments were made after preparing the orthoses and the shoes. In the first session, patients received an AFO with both types of shoes (standard shoes and rocker bottom shoes) along with a 20-minute gait-training program. Then, all of the balance tests were taken from the participants in two conditions, including the AFO with standard shoes and the AFO with the rocker bottom shoes. The tests were performed randomly to minimize the learning effect. A few minutes of rest was given to the patients between two different tests by having them sit on a chair to reduce the effect of fatigue. After the first session, the patients were asked to use the AFO with both shoes for a 3-week adaptation to perform their daily activities. After a 3-week use of AFOs with the stipulated footwear, the measurements were performed again according to the protocol of the first session. Finally, the data obtained in the two test sessions were analyzed and compared to the different conditions of the shoes and between immediately, and after the 3-week adaptation, using the interventions as follows:

- AFO+ standard shoe (immediately) and AFO+ rocker bottom shoe (immediately)
- AFO+ standard shoe (immediately) and AFO+ rocker bottom shoe (after 3 weeks)

Figure 2: Rocker bottom shoe

- AFO+ rocker bottom shoe (immediately) and AFO+ rocker bottom shoe (after 3 weeks)
- AFO+ standard shoe (after 3 weeks) and AFO+ rocker bottom shoe (after 3 weeks)

Outcome Measures

The outcome measurements were evaluated using the clinical assessments in the following:

Walking speed: The walking speed in this study was assessed using the 10-m walk test (10MWT), which measured the total walking distance traveled in 10 meters within a certain period.

Timed-Up and Go (TUG) test: The TUG test is a reliable measurement that assesses mobility, balance, and walking ability. This test needs the patient to stand up from the chair, walk 3 meters at a comfortable pace to a mark placed on the floor, turn around, walk back to the chair, and sit down. [17].

Functional Reach Test (FRT): The FRT measures the maximum distance reached in a forward direction. A yardstick was affixed to the wall for measurement of the reaching distance. The patients were asked to lift an outstretched arm to shoulder height, pause for an initial reading, then reach as far as they could forward without taking a step or losing balance. The starting and ending positions of the index finger for the outstretched arm were recorded, then the difference indicated the total distance for forward direction [18].

Statistical Analysis

An average of three repetitions for each test was recorded. First, the data normality was assessed using the Shapiro-Wilk test. The results showed that data distribution obtained from the four tested conditions was normal in the 10MWT and TUG tests ($P>0.05$) and non-normal in the FRT ($P<0.05$). The paired T-test, therefore, was used to analyze the results of the 10MWT and the TUG test, and the Wilcoxon test was performed to compare the results of the FRT.

Results

In total, 10 stroke individuals were analyzed. For this study, Table 1 indicates the mean and standard deviation of the demographic information of the participants.

The means and standard deviations are demonstrated in Table 2. The amounts of p-value between the comparative conditions that were previously mentioned in the 'Materials and Methods' section are shown in Table 3. Regarding the results of walking speed and

Table 1: Demographic characteristics of patients

Gender	Age (year) mean±SD	Time since a stroke (Month) mean±SD	Paretic side	Height (cm) mean±SD	Weight (kg) mean±SD
M:6 F:4	53.6±7.50	42.5±1.83	R:6 L:4	167.1±5.93	71.30±8.56

M: Male; F: Female; SD: Standard deviation; R: Right; L: Left

Table 2: Mean and standard deviation of data

Parameters	Test conditions			
	AFO + SSh (immediate)	AFO + RSh (immediate)	AFO + SSh (after 3 weeks)	AFO + RSh (after 3 weeks)
Velocity(m/s)	0.49±0.14	0.54±0.14	0.56±0.15	0.64±0.12
TUG (s)	20.51±4.73	19.22±4.73	19.41±4.42	17.54±3.92
FRT (cm)	28.05±4.60	29.10±6.34	29.65±4.87	31.00±5.79

SSh: standard shoe; RSh: rocker shoe, TUG: Timed-Up and Go, FRT: Functional Reach Test. The values are mean± standard deviation

Table 3: Double comparison between the evaluated conditions

Parameters	Comparative conditions (P values)			
	AFO + SSh (immediate) and AFO + RSh (immediate)	AFO + SSh (immediate) and AFO + RSh (after 3 weeks)	AFO + RSh (immediate) and AFO + RSh (after 3 weeks)	AFO + SSh (after 3 weeks) and AFO + RSh (after 3 weeks)
Velocity(m/s)	0.000**	0.000**	0.000**	0.000**
TUG (s)	0.000**	0.000**	0.000**	0.000**
FRT (cm)	0.07	0.041*	0.000**	0.07

SSh: Standard shoe; RSh: Rocker shoe, TUG: Timed-Up and Go, FRT: Functional Reach Test. *P<0.05, **P<0.001

TUG, there was a significant difference in all conditions (P<0.001). So, wearing rocker bottom shoes with the AFO immediately, and after the 3-week adaptation, improved the walking velocity and the time taken in the TUG compared to wearing standard shoes on the AFO (P<0.001). Additionally, utilizing the rocker bottom shoes with the AFO for a 3-week use improved the outcomes of both tests significantly, compared to before using them (P<0.001). Concerning the functional balance in the FRT, there was a statistically significant increase in the rocker bottom shoes with the AFO after a 3-week adaptation in comparison with the immediate use of standard shoes on the AFO (P<0.05), as well as in comparison with immediate use of rocker bottom shoes on the AFO (P<0.001).

Discussion

The purpose of this study was to investigate the effect on hemiplegic stroke patients of rocker bottom shoes with an AFO and the clinical assessments of balance compared to standard shoes with an AFO. Previous studies have shown that using a rocker bottom can have positive results on the gait in those people with Achilles tendinopathy [19], first metatarsophalangeal joint (MTPJ) osteoarthritis [20], diabetics [21], and runners [22], by decreasing the Achilles tendon load. In addition, previous studies have suggested the use of a rocker bottom shoes in cases where the ankle joint is immobilized in a normal 90-degree position, such as arthrodesis or use of an AFO (e.g., an AFO that constrains ankle movement in a patient with muscle weakness due to hemiplegia) [23, 24]. The results of this study presented that use of a rigid AFO with rocker bottom shoes, compared to the use of this orthosis with standard shoes, increased the walking speed and results of the functional tests, including TUG and FRT in individuals who have had a stroke. This confirms the results of Farmani et al. for the TUG test [14]. According to the results of the present study, the rocker bottom added to the front of the shoe (toe-only rocker bottom), along with the rigid AFO, seems to have had some positive effects on functional mobility of the patients, which in turn, increased their walking speed.

The TUG test is often used in measurements related to balance and functional mobility [25]. It has also been shown that this test is a reliable tool for assessing the functional gait of people with medical conditions, including stroke [17]. The results of this study showed that use of AFOs with toe-only rocker bottom shoes reduced the TUG time immediately, and after a 3- week use of the interventions. It can be assumed that reduction in the TUG time with rocker bottom shoes with an AFO was due to the increase walking speed of the patients.

The FRT testing, like other functional balance tests such as the TUG, is highly reliable and is often used to examine various aspects of functional balance activity in mild to moderate hemiplegia patients [26, 27]. The results of the FRT, in this study, demonstrated positive effects in two modes: 1) the rocker bottom shoes with AFO three weeks after wearing, in comparison with immediate use of standard shoes with AFO, and 2) the rocker bottom shoes with AFO three weeks after wearing, in comparison with immediate use of rocker bottom shoes with AFO. Unfortunately, no similar study has been found in this field to compare with the results of this study. However, the improvement in results can be attributed to the fact that toe-only rocker bottoms added to the shoes act like rollers to push the person forward in order to make it easier for them to perform the tests.

Previous studies researched the positive effects on functional balance and gait parameters of AFOs in people with different disabilities. In this study, the improvement of functional balance by using rocker bottom shoes with AFOs, compared to standard shoes with AFOs, can be analyzed as follows: The use of a solid AFO may lead to limited ankle and knee movements and creates an unnatural gait. Rocker bottoms can simulate forefoot dorsiflexion [28] and help forward progression while restricting ankle movements in the sagittal plane [29, 30]. The combination of all these factors can improve functional balance in hemiplegic stroke patients by using rocker bottom shoes with AFOs.

Based on the findings of the present study, wearing a rocker bottom shoe with an AFO improved walking speed and the clinical assessments of balance, therefore, the toe-only rocker bottom in footwear may not have a negative effect for stroke survivors. Stroke patients can wear an AFO with a rigid footplate facilitating rollover function. However, one limitation of the present work was that we were not able to control the time of use of the AFOs with shoes in outdoor. Future studies are recommended to use a force plate device to measure the balance rate of hemiplegic stroke patients while they are using rocker bottom shoes with an AFO.

Conclusion

According to this study, the use of toe-only rocker bottom shoes with an AFO may improve functional mobility, including walking velocity, TUG, and FRT in individuals who have had a chronic stroke.

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Conflict of Interest: None declared.

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