# Comparing the Effect of "Knee Ankle Foot Orthoses" with "Medial Linkage Reciprocal Gait Orthosis" on the Walking Performance and Energy Consumption When Using Conventional KAFO and New MILRGO Orthosis

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## Abstract

**Introduction:** In the present study, the effect of knee angle foot orthosis (KAFO) and medial linkage reciprocal gait orthosis (MLRGO) alongside the reciprocal movement of the MLRGO connected to two KAFOs was tested on a person suffering spinal cord injury and compared with each other. **Materials and Methods**: A person suffering spinal cord injury from thoracic level was chosen randomly to walk with two KAFO and MLRGO orthoses from the patients in red Crescent rehabilitation center. In order to assess the walking speed, distance of walking, and energy consumption, the subject was asked to walk with his self-selected speed in a predetermined path in order to conduct the intended tests. The tests were replicated three times each except for the walking distance test. **Results:** Use of KAFO cause improved walking speed (44.18%), walking distance (125.4%), time of wearing the orthosis (94.67%), and taking off the orthosis (65.43%) compared to the MLRGO. Nevertheless, energy consumption was 17.15% better through MLRGO over KAFO because of its reciprocal movement. **Conclusion:** The results of the present study indicated the superiority of KAFO over MLRGO in a person suffering spinal cord injury regarding spatiotemporal parameters of walking.

**Keywords:** Spinal cord injury, walking ability, KAFO, energy consumption, medial reciprocal linkage

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## Introduction

Spinal cord injury is a damage to the spinal cord, causing loss of sensation and motion from under the site of damage. This damage causes loss of part of performance, sensation, and inability in walking as well as standing of the person (1, 2). The prevalence of traumatic spinal cord injury in Tehran has been reported to be 1.2-11.4 per every 10000 individuals (3). Damage to the spinal cord results in extensive sensory and motor changes. Nevertheless, according to patients, inability of walking is the principal problem they confront after spinal cord injury (2). This injury is accompanied by chronic pain syndrome as well as impaired digestive, urinary, and reproductive system disorders (4).

Usage of wheelchair can help the person with but it is not problem free. The main problem is due to the limited movement arising from the structure of this tool and long sitting. Pressure sores, osteoporosis, and joint deformities (especially hip abduction contracture) are due to long-term sitting on wheelchair (5). Many researchers have reported that encouraging these individuals to use orthosis for long time to exercise has had various physical and psychological effects on them (6, 7). Intervention to improve performance in patients suffering from spinal cord injury includes a combination of pharmacological, surgical, and rehabilitation attitudes (8).

Generally, all of these orthoses can be categorized into three groups: hybrid, powered, and mechanical orthoses (9). Powered orthoses and functional electrical stimulation (FES) system improve walking parameters, but these orthoses are bulky and heavy, and are used very limited in the laboratory environment (10, 11).

***Table 1.*** The spatiotemporal parameters and energy consumption of the participant suffering spinal cord injury in this study

| Spatiotemporal parameters of walking | | | | | Energy consumption variable |
|---|---|---|---|---|---|
| **Type of orthosis** | **Time of wearing off the orthosis (s)** | **Time of taking off the orthosis (s)** | **Distance traversed (m)** | **Walking speed (m/s)** | **Energy consumption (heart rate/min)** |
| **KAFO** | 112.67 (12.7) | 1.53 (74.67) | 21.3 | 0.062 (0.006) | 629.67 (62.13) |
| **MLRGO** | 219.53 (12.26) | 123.53 (23.39) | 9.45 | 0.043 (0.008) | 537.47 (227.37) |

***Figure 1.*** Mold modification stage

***Figure 2.*** KAFO with medial linkage reciprocal joint

Generally, it seems that given the current conditions, mechanical orthoses are the best current solution to support walking for patients with spinal cord injury. Recently, at welfare sciences and rehabilitation University, medial linkage reciprocal orthosis has been fabricated, which enjoys all advantages of medial linkage and reciprocal orthoses (12). So far, this new orthosis, which in addition to being medial linkage, is also reciprocal, has been compared only with isocentric reciprocal orthosis (13). Accordingly, the aim of the present study is to compare medial linkage reciprocal orthosis with a conventional orthosis such as KAFO on walking performance and energy consumption in patients with spinal cord injury.

# Case Report

### *Case history*

A paraplegic 28-year-old man, T9 level, with a height of 175 cm and weight of 78 kg, and based on the inclusion and exclusion criteria, was enrolled in this study. The inclusion criteria were: being a patient of spinal cord injury from thoracic level, at least six months should have passed the damage, no history of using isocentric orthosis, no history of cardiovascular or pulmonary disease, no spasticity beyond 2 (according to Ashworth twice modified criterion), and no contracture in the joint of lower or upper limbs. The exclusion criteria where: the inability of the subject in completing the project or no willingness to participate and continue the study.

### *Combined treatment and clinical assessment in the follow-up*

In this study, a paraplegic person was enrolled according to the inclusion and exclusion criteria. Informed consent form was taken from the patient after explaining the procedure. A suitable standard KAFO was fabricated for the subject after molding at welfare and habitation sciences University (Figure 1). The medial linkage reciprocal joint was also installed on this KAFO in order to conduct the tests related to MLRGO (Figure 2). Before doing the tests, the patient was trained how to walk with the orthoses for 2 weeks, three times per week, and each time 2 hours. These trainings included passive stretching of lower limbs as well as stretching of upper limbs, maintaining balance with the orthosis, standing, and walking with it (14).

After two training weeks, the procedure and tests were completely explained to the subject. Each of the tests was replicated three times, except for the walking distance test, which was done only once because of the person's inability in long walking. After familiarization with the environment and tests, the subject was asked to wear the orthoses. Then, using a chronometer, the time of wearing the orthosis from the beginning until the end was recorded for each orthosis separately (per second) and reported in terms of second.

Also, in this study, the distance traversed by the subject while wearing each orthosis was evaluated using a 6-min walking test (i.e. how far the subject could traverse within 6 min). The distance traversed by the patient while wearing the orthosis was measured and reported in terms of meter. The walking speed in this study was evaluated using 10-meter walking test, which is the distance traversed per unit of time. The distance the person traverses using the orthosis during 10 m was measured, and its time was calculated and reported.

The energy consumption by the person with spinal cord injury in this study was calculated through physiological cost index (PCI) formula, and based on heart rate, oxygen uptake, and using Polar Electro device.

***According to the formula:***

The energy consumption is obtained from subtracting the normal heart rate from heart rate during walking per 1 min (the heart rate per minute) and then dividing it by the average speed.

Eventually, in order to obtain the value of the measured variables and compare these two orthoses, the mean value was calculated for the three tests performed for each variable, and standard deviation was also reported accordingly.

# Results

The variables measured in this study included walking speed, distance traversed within 6 min, time of wearing and taking off the orthosis, and energy consumption. Table 1 indicates the spatiotemporal parameters of the subject during walking with these two orthoses.

The walking speed and distance traversed by KAFO improved by 44.18 and 125.4% compared to MLRGO, respectively. The time of wearing and taking off KAFO compared to MLRGO improved by 94.68 and 65.43%, respectively. Also, the energy consumption during walking improved by 17.15% using the new medial linkage reciprocal orthosis compared to KAFO.

# Discussion

Many patients with spinal cord injury are not able to sand or move. Orthoses and auxiliary devices provide advantages for these patients such as standing and walking in an upright position (15), which itself offers advantages such as pain improvement, reducing fatigue and improving the intestinal as well as bladder function (16), reducing the risk of ulcer (17), and improving bone density (18). Usage of auxiliary devices is observed in more than half of patients with spinal cord injury for walking (19). Isocentric reciprocal and halo orthoses have been expressed to be the most effective orthoses in improving spatiotemporal parameters of walking, which is due to the reciprocal system of these two orthoses (20). Medial linkage reciprocal orthosis is a medial linkage orthosis with a reciprocal system; thus, it enjoys the advantages of reciprocal orthoses. It is indeed the only orthosis which possesses three properties of adapting anatomical joint with orthotic joint, joint placement in the medial section and between two limbs, plus a reciprocal system. This study was performed to investigate the effect of KAFO as a conventional orthosis compared to medial linkage reciprocal orthosis, which was newly designed and fabricated, on the walking parameters of patients with spinal cord injury. The results showed that the walking speed and distance traversed by KAFO improved compared to the new medial linkage reciprocal orthosis.

One of the factors for better approval of orthoses is shorter time of wearing and taking off the orthosis alongside other factors such as better efficiency, aesthetics, and lower energy consumption, etc. In the present study, the time of wearing and taking off KAFO improved compared to the MLRGO. One of the reasons for the longer time of wearing the MLRGO compared to Prime Walk orthosis according to the subject participating in this study is the special shape of the medial linkage reciprocal joint, which is larger, and because of its saddle-like shape, the person should sit on that, and requires more time and greater upper limb power compared to joint free orthosis. This is because the person should lift their trunk and sit on the bed on the saddle-like state of the joint. Generally, the duration of wearing and taking off medial linkage orthoses is longer than that of joint-free KAFO orthoses because of the linkage of the upper internal parts of KAFO orthoses to each other. This is because the person should wear both KAFOs together or take them off, while when these joints do not exist, the person with spinal cord injury can

wear or take off each of the KAFOs separately and with independence and less force. Nevertheless, in spite of these limitations, individuals with spinal cord injury can wear these orthoses alone and on wheelchair, which is an advantage compared to other orthoses such as isocentric reciprocal orthosis, which has also a trunk part.

In two review studies performed by Arazpour and Ahmadi respectively, the walking speed was reported to be higher using a medial linkage orthosis such as Walk Abbot compared to KAFO (11, 21). However, the present study found the opposite. The sample size of the research conducted in these two review studies was at least 4 cases, while the sample size of the present study was only one case, which may explain this difference. Generally, one of the reasons of low walking speed with orthoses is the fixation of the foot ankle joint. Another reason is the high weight of these joints negatively affecting the walking speed and energy consumption.

Based on findings of this study, the energy consumption during walking improved when using the MLRGO compared to KAFO. Improvement of movement and walking ability with optimal energy may ameliorate the quality of life-associated health in individuals with spinal cord injury (22). Generally, energy consumption when using orthoses has been reported to be higher compared to applying wheelchair (23, 24). Nevertheless, long-term use of wheelchair causes problems such as pressure sores, osteoporosis, and joint deformities (especially hip abduction contraction) (5). Gonda, Ahmadi et al. stated that the best solution for reducing energy consumption is use of a medial linkage orthosis with a reciprocal part (9, 25). The results obtained from this study also indicated diminished energy consumption using MLRGO compared to KAFO, which is possibly due to the reciprocal system of the medial linkage orthosis. One of the limitations of the present study was the small sample size, which was somehow due to the expensiveness of medial linkage reciprocal orthosis. Also, due to the inability of the subject in long walking, the test of distance traversed by the person was done only once.

## Conclusion

The present study suggests that unexpectedly, MLRGO compared to KAFO did not cause improved walking parameters such as the distance traversed and walking speed. Further, the time of wearing the MLRGO was longer than that of KAFO, while energy consumption decreased when using MLRGO compared to KAFO. Thus, further studies with larger sample sizes are required to achieve the preferred orthosis in patients with spinal cord injury.

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## References

1. Capaul M, Zollinger H, Satz N, Dietz V, Lehmann D, Schurch B. Analyses of 94 consecutive spinal cord injury patients using ASIA definition and modified Frankel score classification. Paraplegia. 1994;32(9):583-7.
2. Nene AV, Hermens HJ, Zilvold G. Paraplegic locomotion: A review. Spinal cord. 1996;34(9):507-24.
3. Rahimi-Movaghar V, Saadat S, Rasouli MR, Ganji S, Ghahramani M, Zarei M-R, et al. Prevalence of spinal cord injury in Tehran, Iran. The journal of spinal cord medicine. 2009;32(4):428-31.
4. Ebel A. Restorative management of paraplegic patient. Philosophy and concept of bracing. New York state journal of medicine. 1968;68(15):2037-40.
5. Douglas R, Larson PF, D'Ambrosia R, McCall RE. The LSU Reciprocation-Gait Orthosis. Orthopedics. 1983;6(7):834-9.
6. Summers BN, McClelland MR, El Masri WS. A Clinical Review of the Adult Hip Guidance Orthosis (Para Walker) in Traumatic Paraplegics. Paraplegia. 1988;26(1):19-26.
7. O'Daniel WE, Jr., Hahn HR. Follow-up usage of the scott-craig Orthosis in paraplegia. Paraplegia. 1981;19(6):373-8.
8. Steeves JD, Lammertse D, Curt A, Fawcett JW, Tuszynski MH, Ditunno JF, et al. Guidelines for the conduct of clinical trials for spinal cord injury (SCI) as developed by the ICCP panel: clinical trial outcome measures. Spinal cord. 2007;45(3):206-21.
9. Genda E, Oota K, Suzuki Y, Koyama K, Kasahara T. A new walking orthosis for paraplegics: hip and ankle linkage system. Prosthetics and orthotics international. 2004;28(1):69-74.
10. Karimi MT. Functional walking ability of paraplegic patients: comparison of functional electrical stimulation versus mechanical orthoses. European journal of orthopaedic surgery & traumatology orthopedie traumatologie. 2013;23(6):631-8.

11. Arazpour M, Bani MA, Hutchins SW. Reciprocal gait orthoses and powered gait orthoses for walking by spinal cord injury patients. Prosthetics and orthotics international. 2013;37(1):14-21.
12. Ahmadi Bani M, Arazpour M, Farahmand F, Azmand A, Hutchins SW, Vahab Kashani R, et al. The influence of new reciprocating link medial linkage orthosis on walking and independence in a spinal cord injury patient. Spinal Cord. 2015;53:S10-S2.
13. Ahmadi Bani M, Arazpour M, Farahmand F, Kashani RV, Mousavi ME, Hutchins SW. Comparison of new medial linkage reciprocating gait orthosis and isocentric reciprocating gait orthosis on energy consumption in paraplegic patients: a case series. Spinal Cord Ser Cases. 2015;1:15012.
14. Ahmadi Bani M, Arazpour M, Farahmand F, Sefati S, Baniasad M, Hutchins SW, et al. Design and analysis of a new medial reciprocal linkage using a lower limb paralysis simulator. Spinal cord. 2015;53(5):380-6.
15. Behrman AL, Harkema SJ. Physical rehabilitation as an agent for recovery after spinal cord injury. Physical medicine and rehabilitation clinics of North America. 2007;18(2):183-202.
16. Eng JJ, Levins SM, Townson AF, Mah-Jones D. Use of prolonged standing for individuals with spinal cord injuries. Physical therapy. 2001;81(8):1392.
17. Correa G, Fuentes M, Gonzalez X, Cumsille F, Pineros J, Finkelstein J. Predictive factors for pressure ulcers in the ambulatory stage of spinal cord injury patients. Spinal cord. 2006;44(12):734-9.
18. Dionyssiotis Y, Lyritis G, Mavrogenis A, Papagelopoulos P. Factors influencing bone loss in paraplegia. Hippokratia. 2011;15(1):54-9.
19. Saensook W, Phonthee S, Srisim K, Mato L, Wattanapan P, Amatachaya S. Ambulatory assistive devices and walking performance in patients with incomplete spinal cord injury. Spinal cord. 2014;52(3):216-9.
20. Bani MA, Arazpour M, Farahmand F, Sefati S, Baniasad M, Hutchins S, et al. Design and analysis of a new medial reciprocal linkage using a lower limb paralysis simulator. Spinal cord. 2015;53(5):380.
21. Ahmadi Bani M, Arazpour M, Farahmand F, Mousavi ME, Hutchins SW. The efficiency of mechanical orthoses in affecting parameters associated with daily living in spinal cord injury patients: a literature review. Disability and rehabilitation Assistive technology. 2015;10(3):183-90.
22. Jain NB, Sullivan M, Kazis LE, Tun CG, Garshick E. Factors associated with health-related quality of life in chronic spinal cord injury. American journal of physical medicine & rehabilitation/Association of Academic Physiatrists. 2007;86(5):387.
23. Cerny D, Waters R, Hislop H, Perry J. Walking and wheelchair energetics in persons with paraplegia. Physical therapy. 1980;60(9):1133-9.
24. Wolfe G. Influence of floor surface on the energy cost of wheelchair propulsion. The Orthopedic clinics of North America. 1978;9(2):367-70.
25. Bani MA, Arazpour M, Ghomshe FT, Mousavi ME, Hutchins SW. Gait evaluation of the advanced reciprocating gait orthosis with solid versus dorsi flexion assist ankle foot orthoses in paraplegic patients. Prosthetics and Orthotics International. 2013;37(2):161-7.