

Hybrid FES with the Medial Single Hip Joint Knee-Ankle-Foot Orthoses in a T4 Complete Paraplegic Patient

T.Minato*, Y.Shimada*, K.Sato*, Y.Tsutsumi*, T.Matsunaga*,
A.Misawa*, S.Ando*, M.Sato**, S.Chida**, K. Hatakeyama**, K. Iizuka***
*Department of Orthopedic Surgery, Akita University School of Medicine, Akita Japan
**Rehabilitation Division, Akita University Hospital, Akita Japan
***BIOTEC, LTD

E-mail: takaplio@doc.med.akita-u.ac.jp

Abstract – *The medial single hip joint Knee-Ankle-Foot Orthoses (MSH-KAFO) was used during paraplegic gait. However, the gait velocity was slow and the step length was small. A new device called slide-MSH reportedly has superior gait than that of the Walkabout orthosis in gait velocity, cadence, and stride.*

In this study, the gait of the MSH-KAFO and the slide-MSH-KAFO were compared. The conditions of only orthosis with or without FES (hybrid FES) in a T4 complete paraplegic patient were examined. The results of the two orthoses with FES were greater than that with only orthosis in both step length and gait velocity. Furthermore, the results of the slide-MSH-KAFO with FES were significantly greater than all other conditions in these parameters. The slide-MSH for hybrid FES improved gait velocity and step length compared to the MSH in a T4 complete paraplegic patient.

Keywords: functional electrical stimulation, hybrid FES, paraplegia, MSH-KAFO, Primewalk

1. Introduction

The medial single hip joint Knee-Ankle-Foot orthosis (MSH-KAFO) called the Walkabout orthosis was invented by S. McKay in 1992 [1] (Fig. 1). This orthosis enables stable paraplegic standing and walking that is compatible with a wheelchair. It is easy don - doff and enables the patient to stand up independently from a wheelchair using functional electrical stimulation.

However, the gait velocity is slow and step length is small due to discrepancy between the single hip joint axis and the physiological hip joint axis which restricted the range of motion of the hip. The new medial linkage, invented by Saito in 1997 [2], solves this issue (fig 2). This device which is known as slide-MSH (Primewalk), utilizes a sliding arc guide that has a virtual axis near the physiological hip joint. The reconstruction of paraplegic gait was superior to the single hip joint orthosis in gait velocity, cadence, and stride.

As the complete T4 paraplegic patient's gait was

reconstructed using hybrid FES with the Walkabout orthosis, the gait velocity was slow and step length was small.

The purpose of this study is to compare the gait in complete a T4 paraplegic patient between the Walkabout orthosis and the Primewalk orthosis using only orthosis or the orthosis with FES respectively.

2. Methods



Fig. 1: The Walkabout orthosis has single hip joint.

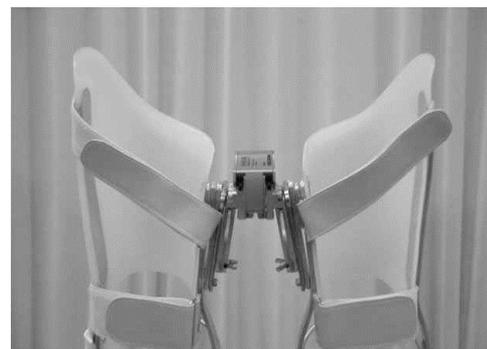


Fig. 2: The Primewalk orthosis has sliding arc guide.

A 21-year-man with complete T4 paraplegia participated in this study. He was injured in a traffic accident 1.5 years ago. The percutaneous intramuscular electrodes were implanted for FES to reconstruct ambulation 1.1 years ago. The electrodes were implanted

in the femoral nerve, the perineal nerve, the psoas major muscle, the vastus lateralis and medialis muscles, the sartorius muscle, the tensor fascia latae muscle, the adductor muscles, the gluteus maximus and medius muscles, the biceps femoris muscles, and the paravertebral muscles. The hybrid FES gait was reconstructed with the Walkabout orthosis and parallel bars for 9 months.

The Akita Stimulator FES system was used (BIOTECH, LTD, Japan). It has 16 channels and 2 hand switches that enabled reciprocal walking. When the hand switch is on, the psoas muscle, the femoral nerve and the paravertebral muscle are stimulated and the hip joint is flexed. When the hand switch is off, the femoral nerve, the gluteus maximus muscles and the hamstrings are stimulated and the hip joint is extended. Thus the patient controls the hand switches alternatively and reciprocal gait is achieved. The electrical stimulation used were rectangular pulse trains that consisted of a pulse width of 0.2 msec, pulse interval of 50 msec, and output voltage modulated from 0 to -15V.

The patient wore the Walkabout orthosis or the Primewalk orthosis and walked at subject's self-selected gait speed using parallel bars. The gait was measured over 5 meter excluding the first 3 steps and was repeated 10 times respectively. The gait conditions were the Walkabout orthosis gait, the Walkabout orthosis with FES gait, the Primewalk orthosis gait, and the Primewalk orthosis with FES gait.

The evaluation parameters were the step lengths, the step cadences and the gait velocity. These aspects of the gait were measured using the PEAK motion analysis system (Mortus, LTD, America) and each parameter was assessed statistically. The reflection points for the PEAK motion analysis system were placed on the head, both of the acromions, elbows, wrists, greater trochanters, knees and ankles.

3. Results

The step length was $0.16 \pm 0.03\text{m}$ (Mean \pm SD) with the Walkabout orthosis (WO), $0.26 \pm 0.04\text{m}$ with the Walkabout orthosis using FES (WO/FES), $0.17 \pm 0.03\text{m}$ with the Primewalk orthosis (PO) and $0.30 \pm 0.05\text{m}$ with the Primewalk orthosis using FES (PO/FES). The Primewalk orthosis using FES performed significantly better than the Walkabout orthosis and FES ($p < 0.05$; Student's t-test). However, there was no significant difference between the Walkabout and the Primewalk only orthosis gait. All orthoses gaits with FES were significantly better than that of the only orthosis ($p < 0.05$; Student's t-test) (Fig. 1).

The step cadence was 29 ± 1 steps/min (Mean \pm SD)

with the Walkabout orthosis (WO), 24 ± 2 steps/min with the Walkabout orthosis using FES (WO/FES), 28 ± 2 steps/min with the Primewalk orthosis (PO) and 22 ± 2 steps/min with the Primewalk orthosis using FES (PO/FES). All orthosis gaits with FES performed significantly better than that of only orthosis ($p < 0.05$; Student's t-test). However there was no significant difference between the Walkabout and the Primewalk when FES was used and it was not used (Fig. 2).

The gait velocity was $4.94 \pm 0.16\text{m/min}$ (Mean \pm SD) with the Walkabout orthosis (WO), $5.59 \pm 0.21\text{m/min}$ with the Walkabout orthosis using FES (WO/FES), $4.99 \pm 0.36\text{m/min}$ with the Primewalk orthosis (PO) and $6.09 \pm 0.17\text{m/min}$ with the Primewalk orthosis using FES (PO/FES). The gait of the Primewalk orthosis using FES was significantly better than that of the Walkabout orthosis using FES ($p < 0.05$; Student's t-test). All orthoses using FES gait were significantly greater than that of only orthosis ($p < 0.05$; Student's t-test). There was no significant difference between the Walkabout orthosis and the Primewalk orthosis when FES was not used (Fig.3).

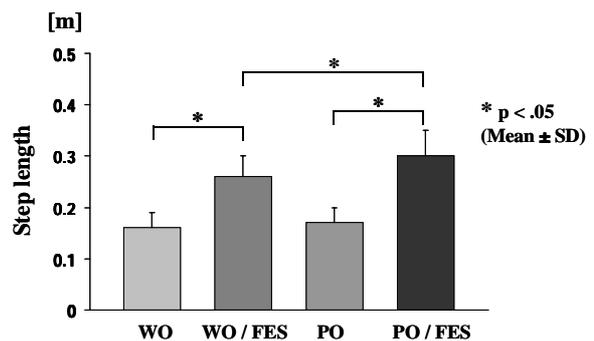


Fig. 1: The step lengths of both orthoses using FES were significantly better than that of only orthoses. The step length with the Primewalk orthosis using FES was longer than the Walkabout orthosis using FES. There was no significant difference between both orthoses when FES was not used.

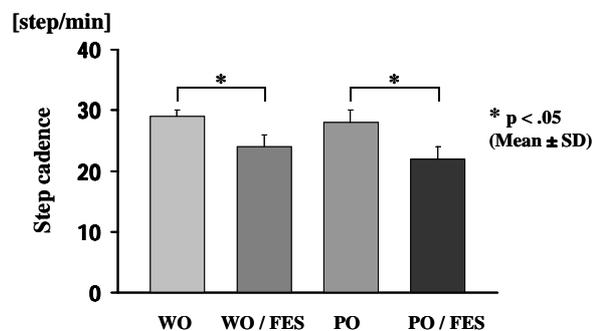


Fig. 2: The step cadences of both orthoses using FES were less than that of only orthoses. There was no significant difference between both orthoses when FES was used and it was not used.

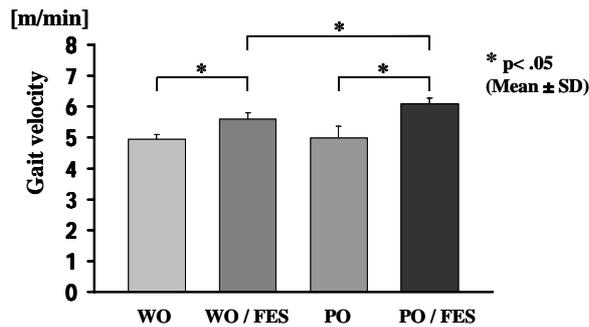


Fig. 3: The gait velocities of both orthoses using FES were significantly better than that of only orthoses. The gait velocity of the Primewalk orthosis using FES was significantly better than the Walkabout orthosis using FES. There was no significant difference between both orthoses when FES was not used.

4. Discussion

The gait velocity and step length was improved using FES rather than only orthosis gait. In paraplegic gait, the leg swings is dependent on the acceleration due to inertia with the only orthosis gait, though FES added muscular strength and assisted to swing leg. There were significant differences between the Walkabout and the Primewalk for the hybrid FES gait as regards the step length and the gait velocity. Saito explained the mechanism of the restriction of the hip ability in MSH has the discrepancy of the axes between MSH and the physiological hip joint [2]. When a patient swings the leg more longly in the Walkabout orthosis, this discrepancy caused his pelvic to rotate and restricted the movement of the hip. Middleton also argued that the discrepancy creates a significant impediment to ambulation by increasing resistance to movement of the legs and invented the Moorong Medial Linkage Orthosis (Moorong MLO) which consists of an arced sliding link centered on the hip joint with rolling element bearings to minimize friction [3]. The concepts of the Moorong MLO

and the Primewalk were very similar at the point of the improvement of the restricted movement of the legs due to the axis positioned closely by sliding mechanism. However, the movement of the hip was not so restricted by the Walkabout orthosis if the step length was small. Then there were no significant differences between the parameters of the Walkabout and the Primewalk in only orthosis gait. Therefore the Primewalk orthosis with FES greatly improved the step length and gait velocity.

There was the tendency that when the step length was longer, the step cadence was smaller. It indicated that when the step length was longer, the forward movement was slower. Due to the high-level thoracic spinal cord injury, such as in T4 complete paraplegic patients, it was quite difficult to move forward fast due to the widespread trunk instability. There were no significant differences between both orthoses.

5. Conclusion

The hybrid FES is more useful for the ambulation and furthermore the Primewalk orthosis improved the step length and the gait velocity in comparison with the Walkabout orthosis in a complete T4 paraplegic patient.

References

- [1] Kirtley C and McKay SK, (1992) A medially mounted orthotic hip joint for paraplegic walking systems preliminary reports on the "Polymedic walker" device. *Polymedic technical note*, Australia.
- [2] Saitoh E, Baba M, Sonoda S, Tomita Y, Suzuki M, Hayashi M, (1997) A new medial single hip joint for paraplegic walkers, *The 8th World Congress of the International Rehabilitation Medicine Association (IRAM)*, 1299-1305.
- [3] Middleton JW, FISHER W, DAVIS GM and SMITH RM, (1998) *Prosthetics Orthotics International*, 22:258-264.