

COMPARISON OF OXIDATIVE ENERGY CONSUMPTION DURING WALKING USING THE WALKABOUT AND THE PRIMEWALK IN PARAPLEGIA

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Abstract: *Medially single hip joint knee-ankle-foot orthosis (MSH-KAFO) such as the Walkabout or Primewalk is effective in restoring a stable standing posture in paraplegia. To evaluate the energy consumption of during walking with the Walkabout and the Primewalk, both using the FES system, T12 level complete paraplegic subject participated in this study. We measured oxygen consumption during self-selected comfortable walking MSH-KAFO and the L-walker. The oxidative energy consumption, walking velocities, step length and step cadence were calculated. The average speeds of walking were 16.7 ± 1.6 m/min with the Primewalk, 16.8 ± 1.4 m/min with the Walkabout, 18.3 ± 0.3 m/min with the Primewalk and FES, and 17.3 ± 0.4 m/min with the Walkabout and FES. No statistical differences were observed in step length when walking with or without FES were compared. The step cadence increased in MSH-KAFO+FES compared with MSH-KAFO. During Primewalk walking, energy consumption was significantly different ($p < 0.05$) depending on whether FES was used or not. This study showed that the Primewalk using a multi-channel FES system was more effective in decreasing the effort of walking in paraplegic patients.*

Keywords: energy consumption, Walkabout, Primewalk, functional electrical stimulation, gait

1. Introduction

Functional electrical stimulation (FES) with hybrid orthosis is effective in restoring the function of walking in paraplegic patients. Recent papers have reported the oxidative energy consumption of paraplegic's walking using hybrid FES. Medially single hip joint knee-ankle-foot orthosis (MSH-KAFO), such as the Walkabout [1] or Primewalk [2], are effective in restoring a stable standing posture in paraplegia. However,

these orthoses do not mechanically assist hip flexion in walking. The Primewalk is the new version of the MSH-KAFO, modified from the Walkabout. The major difference between these systems is the hip joint position.

Although there are several papers on oxygen consumption and oxidative energy consumption, physiological studies described in regard to Walkabout and Primewalk are few [3][4][5][6]. The purpose of this study was to evaluate the oxidative energy consumption during walking with the Walkabout and the Primewalk using FES in paraplegia.

2. Subject and methods

A 22 year-old T12 complete paraplegic subject, treated with FES using percutaneous intramuscular electrodes and Akita system II, participated in this study. The time since onset was 3 years. The time since TES supply was 3 years. The number of percutaneous electrodes was 10. The subject used the Walkabout for over 2 years, and the Primewalk for over a year.

To restore the function of walking, FES was used (Fig 1).

The subject walked at a self-selected comfortable speed using reciprocal walking over a flat surface using the Walkabout and Primewalk with an L-walker for 60m. Measurements were randomized and repeated 7 times during an 8-week period. Cardiopulmonary data were collected using a portable telemetric system K4b2 (Cosmed, Italy) via breath-by-breath methods. This system measured the concentration and volume of gases expired through a tight-fitting facemask, and was carried on the subject's chest; the heart rate was monitored using chest electrodes.

We evaluated gait velocity, step length, step cadence, and energy consumption. The Wilcoxon paired test was



Fig 1. Subject's hybrid-FES walking with an L-walker

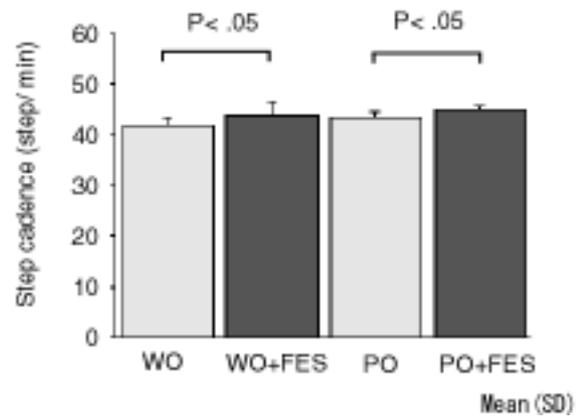


Fig 2. Step cadence during walking with the Walkabout and the Primewalk. The step cadence was greater with MSH-KAFO+FES than MSH-KAFO ($p < .05$).

WO: Walkabout PO: Primewalk

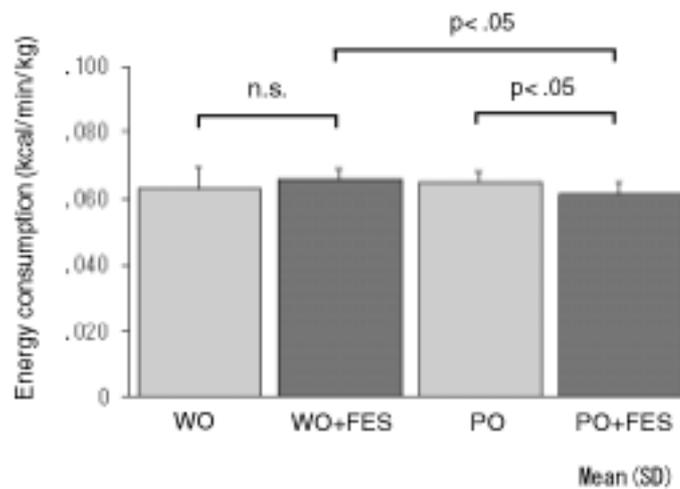


Fig 3. Energy consumption during walking with the Walkabout and the Primewalk. Energy consumption was lower in the Primewalk and FES ($p < .05$).

WO: Walkabout PO: Primewalk

n.s.: no significance

used for physiological data during the last 1 minute of walking. Walking speed during the last 50m of each kind of walking was also compared.

3. Results

The average speeds of walking were 16.7 ± 1.6 m/min (Mean \pm SD) with Primewalk, 16.8 ± 1.4 m/min with Walkabout, 18.3 ± 0.3 m/min with Primewalk and FES, and 17.3 ± 0.4 m/min with Walkabout and FES. Whether

or not FES was used, no statistical differences were observed between either the gait velocities or step length during walking. The step cadence increased in MSH-KAFO+FES compared with MSH-KAFO (Fig.2). During Primewalk walking, energy consumption was significantly different ($p < 0.05$) between with FES use and FES non-use.

Primewalk showed less energy consumption compared with the Walkabout (Fig.3).

4. Discussion

The hip joint position in the Walkabout is lower than the physiological hip joint position. From the standpoint of the efficiency of walking, the large coronal pelvic rotation, hip instability, and low gait velocities have been pointed out. Saitoh et al. [2] developed a modified medial single hip joint (Primewalk) to solve the discrepancy of height between the axes of the joints in Walkabout. Primewalk is the slide type MSH. Recently the Moorong MLO, with an arcuate sliding linkage centered on the hip joints, that is similar to the Primewalk, was used on a C6 tetraplegic patient, and showed a slight increase in gait velocity and a lower oxygen cost compared to the Walkabout [6].

Previous study showed that the Primewalk using FES caused significant increase in stride, cadence, and velocity, compared with the Walkabout using FES in a T8 complete paraplegia [7].

There have been few reports referring to the FES walking with MSH. Saitoh et al. [3] showed that Walkabout using FES causes superiority in stride, cadence, and velocity compared with HKAFO in a T10 complete paraplegic patient. Hatakeyama et al. [4] described that the metabolic parameters of walking with the Primewalk were greater than those with the Walkabout in a T12 complete paraplegic patient. We [5] reported that the Walkabout using FES produces less energy consumption in maximum-speed walking compared with non-FES. Our results show lower energy consumption with the Primewalk, suggesting improved partial efficiency of walking with this device. Although it is not clear what influenced the discrepancy of energy consumption, our results suggest that, in this single case study, the Primewalk using multi-channel FES system is more effective in decreasing the effort of walking in paraplegic patients. Further study is necessary in defining the exact mechanism associated with arcuate sliding linkage and the efficiency of energy consumption that is responsible for the improvement in FES walking.

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