

COMPARISON OF L-WALKER WITH CRUTCH IN OXYGEN CONSUMPTION DURING WALKING WITH WALKABOUT AND HYBRID FES IN PARAPLEGICS

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ABSTRACT

In order to restore gait performance in complete paraplegics, multi-channel functional electrical stimulation was used together with orthotic devices (hybrid FES). Recently, the Walkabout (medial single hip joint attached to long leg braces) is commonly used for walking in paraplegic patients treated by functional electrical stimulation. The purpose of this investigation is to evaluate cardiopulmonary stress differences in paraplegics walking with an L-walker and paraplegics walking with crutches. T12 and L1 level incomplete paraplegic patients, 21 and 30-years-old, treated with functional electrical stimulation using percutaneous intramuscular electrodes, participated in this study. The walking exercise was maximum-speed walking using the Walkabout and either an L-walker or crutches for a 60m distance. A portable telemetric system K4b² (Cosmed Ltd, Rome) was used to measure oxygen consumption (VO₂), pulmonary ventilation (VE), and heart rate via breath-by-breath methods during the trials. The oxidative energy consumption, walking velocities, step length and step cadence were also calculated. The average speed of walking ranged from 7.5 to 24.5m/min. The oxidative energy consumption ranged from 0.053 to 0.077 kcal/min/kg. Significant differences ($p < 0.05$) were found between walking velocities, step cadence, step length, and energy consumption ($\text{kcal} \cdot 10^{-3} / \text{m/kg}$). No statistical differences were observed between heart rate, VO₂, VE and oxidative energy consumption ($\text{kcal}/\text{min}/\text{kg}$). The results suggest that the maximum-speed walking for incomplete paraplegic patients using the Walkabout does not change the energy consumption although the degree of control in the trunk and lower-extremities was different.

Keywords: oxygen consumption; functional electrical stimulation; gait; spinal cord injury; Walkabout

INTRODUCTION

Reconstructive standing and walking functions in paraplegics are valuable for preventing medical problems involving cardiovascular deconditioning. Recently, the Walkabout (medial single hip joint attached to the long leg braces) ¹⁻³ is commonly used for walking in our paraplegic patients treated by functional electrical stimulation (FES). The Walkabout seemed to have many merits in functions of standing and walking, wheel chair compatibility, cosmesis, and easy don-doff². The purpose of this investigation is to evaluate cardiopulmonary stress differences in paraplegics walking with an L-walker and paraplegics walking with crutches.

MATERIALS AND METHODS

T12 and L1 level incomplete paraplegic subjects (cases 1 and 2), 21 and 30-years-old, participated in this study (Table 1). Both subject used the Walkabout over 6 months in their home and did not go outdoors.

The FES system developed by Sendai Group was used. The indwelling electrode was formed from 19 strands of a helically wound Teflon-coated stainless steel (Nippon Seisen Co.Ltd). Electrodes were percutaneously implanted into the motor point. The electrodes implanted near the common peroneal nerve provided stimulation for hip flexion by eliciting the preserved flexion withdrawal reflex. Rectangular pulse trains consisted of a pulse width of 200 microseconds, a pulse interval of 50ms, and a pulse amplitude from 0 to -15 V. Therapeutic electrical stimulation (TES) was used to train paralyzed muscles 3 to 5 times daily over a 2-year period.

The FES system using Akita system was used in a T12 incomplete paraplegic patient (case 1) to restore the function of walking. FES control during walking was as follows: when the grip sensor was on, the iliopsoas muscle contracted to swing the leg by means of the withdrawal reflex when the peroneal nerve was stimulated.

Before the walking exercise, the subject sat for 5 minutes before standing up with a walker from a wheel-chair. Standing was maintained until heart rate and respiratory gas changes became stable for 3 to 5 minutes. The walking exercise was maximum-speed reciprocal walking over a flat surface using the Walkabout and either an L-walker or elbow crutches for a 60m distance. The tests were randomized and repeated 7 times during 8 weeks. Physiologic data were collected using a portable telemetric system K4b² (Cosmed Ltd, Rome) via breath-by-breath methods. This system was carried on the subject's chest and measured the concentration and volume of gases expired through a tight-fitting face mask; the heart rate (HR) was monitored from chest electrodes. The oxidative energy consumption (EC), walking velocities, step length and step cadence were also calculated.

Wilcoxon paired test was used for cardiopulmonary data during the last 1 minute of walking, and other physiological data during the last 50m distance were used to compare the two kinds of walking. Statistical analysis revealed significant differences ($p < 0.05$).

Table 1. Characteristics of the subjects

Subject	Sex	Age	Level of injury (yr)	Time since onset (yr)	Time since TES supply (yr)	Number of electrodes
1	Male	21	T12	2	2	10
2	Male	30	L1	6	5	20

Table 2. Comparison of measurements

	Case1			Case2	
	Crutches	Walker	Walker+FES	Crutches	Walker
Velocity (m/min)	12.3 (1.7)	21.1* (1.9)	24.5 (1.8)	10.0 (0.4)	7.5* (0.6)
Step cadence (step/min)	43.3 (2.7)	48.2 (1.9)	51.4 (2.5)	52.0 (2.3)	45.1* (1.9)
Step length (m)	0.28 (0.02)	0.44* (0.03)	0.48# (0.02)	0.19 (0.01)	0.17 (0.01)
Heart rate (beat/min)	133.3 (12.4)	133.2 (13.7)	133.3 (10.1)	155.8 (5.6)	149.3 (5.8)
VO2 (mL/min)	857.4 (87.1)	916.1 (87.6)	808.7 (87.2)	733.8 (130.7)	766.9 (37.6)
VE (L/min)	33.5 (3.2)	35.2 (4.7)	32.1 (3.2)	24.8 (4.7)	22.6 (1.4)
Energy consumption (kcal/min/kg)	0.072 (0.008)	0.077 (0.007)	0.067# (0.005)	0.053 (0.010)	0.055 (0.003)
Energy consumption (kcal · 10 ⁻³ /m/kg)	5.92 (0.27)	3.67* (0.12)	2.77# (0.41)	5.30 (1.02)	7.31* (0.72)

Mean (SD)

* Significant difference between Crutches and Walker, $p < .05$.# Significant difference between Walker and Walker+FES, $p < .05$.

RESULTS

Table 2 showed the results of comparison of measurements. The average speed of walking ranged from 7.5 to 24.5m/min. In case 2, walking velocity decreased using crutches compared with the walker. The oxidative EC ranged from 0.053 to 0.077kcal/min/kg. Significant differences ($p < 0.05$) were found between walking velocities, step cadence, step length, and EC (kcal·10⁻³/m/kg). No statistical differences were observed between HR, VO2, VE, and EC (kcal/min/kg).

In case 1 step length increased, and decreased EC in walker+FES compared with walker.

DISCUSSION

Orthotic devices for paraplegic standing and walking are normally used. Walkabout orthosis has its initial appeal because it eliminates the need for a thoracolumbar brace. However, during testing T9-T12 paraplegics have a high energy cost for ambulation and a slow walking speed, although at a self-selected comfortable and constant pace³. Considering the main physiological variables, VE (L/min), HR (beats/min), and VO2 (mL/kgmin) were not significantly different, whether Walkabout Orthosis or Isocentric Reciprocal Gait Orthosis were used. Our results suggest that these physiological variables also not differ significantly during maximum-speed walking, except when considering the various skill levels of the orthotic users. Although the degree of control in the trunk and lower-extremities did vary

between crutches and the walker, axillary load on the crutch or grip required muscle endurance or muscle power from the upper extremities or trunk, so that the magnitude of these physiological responses coincides with the subjects' perceptions of a "maximum" level of exertion.

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