

# **FES augmented partial weight-bearing support treadmill training in acute incomplete SCI patients**

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## Introduction

Restoration of mobility is a major goal in the rehabilitation of the spinal cord injured (SCI) patient. While successful re-integration of the SCI patient into home and work environment is possible without the patient regaining the ability to ambulate, maximisation of the patient's walking ability is very desirable. In a recent survey of the UK and Dutch SCI population it was found that 90% of SCI patients who regained some useful walking ability had incomplete spinal cord injuries (ISCI) [1]. This survey also showed an overwhelming preference for gait improvements in the ISCI population compared to the SCI population as a whole.

Early intervention with the ISCI patient is essential in maximising his potential functional recovery. However, present physiotherapy practice often rules out early gait training with these patients.

Recently there have been a growing number of research studies looking into the effects of Partial Body Weight Support (PBWS) treadmill gait training, in individuals with central neurological impairments. The benefits of using PBWS and a treadmill for gait re-education are two-fold. PBWS and treadmill training has been shown to generate cord based stepping movements due to the afferent input from the partially loaded limbs. This effect has been correlated with reductions in mobility related measures of disability in these patients [2]. PBWS and treadmill training also frees the therapist(s) from having to support the patient when he is unable to weight bear and allows the therapist to concentrate on encouraging normal stepping movements. However with PBWS treadmill based gait training there is still considerable effort required from the therapist(s) to guide the movements of the patient's legs.

Although the use of PWBS in conjunction with a treadmill offers increased safety for a subject undergoing gait training, and frees the therapist(s) from supporting the subject, considerable effort may be required from the therapist(s) to guide the movements of the subject's lower limbs. This is particularly pertinent in the case of acute ISCI individuals who have not commenced gait training and are initially nonambulatory. One approach to reducing the physical demand on the therapist(s) is the use of FES to elicit stepping and assist stance phase support. Hesse et al [3] demonstrated that a combination of FES and PWBS treadmill training was more effective than standard physiotherapy in terms of restoration of gait function in a group of 11 chronic hemiparetic patients. Recently this technique has been applied to chronic ISCI subjects [4]. A total of 19 subjects who were at least 12 months post injury, with asymmetrical lower extremity function, received 1.5 hours of treadmill training per day, for three days per week for three months. This resulted in increased walking speed and lower extremity muscle strength.

To date there have been no reports on the use of the combination of FES and PWBS treadmill training in patients during the acute phase of spinal cord injury. This approach could offer great potential, as early intervention with ISCI patients is essential in maximising their functional recovery.

The aim of this study was to explore the combination of FES with PWBS treadmill gait training in the rehabilitation of acute ISCI subjects, and to compare this with standard physiotherapy intervention.

## Methods

Fourteen subjects, twelve male and two female, who had an ISCI with some level of motor function below the level of injury (ASIA categories C and D), were recruited into the study as soon as they were deemed to be medically stable and could be stood upright without complications. Mean time post injury was 12.2 weeks (SD 5.9 weeks). Two subjects withdrew from the study and only one subject had performed any gait training prior to recruitment. Ethical approval was granted by the local Trust ethical committee prior to the commencement of the study, and all subjects gave their informed consent at the time of recruitment.

This study used a single case experimental design, with each subject acting as their own control. Subjects underwent a control period and an intervention period, each lasting four weeks, including a three day assessment session at the end of each period. The subjects were randomly assigned to either an AB (control – intervention) or BA (intervention – control) sequence. During the control period (A) subjects received their standard physiotherapy. During the intervention period subjects received daily gait training on the treadmill for five days per week.

Subjects were supported over the treadmill by means of a harness with the partial weight support provided by a weight stack connected to the harness via a pulley system. The PWBS system was developed in-house. FES strategies were individually tailored to suit the requirements of each subject, with up to four channels of stimulation being used. Figure 1 shows a subject walking on the treadmill with PWBS and FES.



Figure 1 Subject walking on the treadmill with PWBS. FES was applied bilaterally to assist knee extension during stance phase and to elicit the flexion withdrawal response in swing phase to assist stepping. Initially the investigators were present to guide the limbs and place the feet. Later during the intervention period the subject was able to walk on the treadmill using FES and without any assistance from the investigators.

Subjects typically began training with PWBS of at least 40% of body weight. During subsequent training sessions the weight support was gradually decreased should the subject's ability have improved sufficiently. Treadmill speed, trunk support and FES parameters were also modified accordingly. Subjects walked for as long as they could, up to a maximum 25 minutes, and were allowed to take rests when required. Intervention sessions lasted for approximately one hour, including donning and doffing of the harness and stimulator and rest periods.

Each subject's walking ability was assessed prior to the first randomly assigned period (control or intervention) to obtain baseline measures, and in the final week of each control and intervention period. Over ground walking endurance, the total distance walked in a six minute period around a 22m figure eight track at self selected speed,

was recorded on five occasions in each period. Appropriate walking aids were selected for each subject. Over ground walking speed, cadence and stride length were all measured over a 6m walkway and recorded on 10 occasions in each period. Observational gait analysis from video was performed once for each period, incorporating bilateral sagittal plane views and anterior and posterior coronal plane views. Quality of gait was scored according the Ranchos Los Amigos Observational Gait Analysis Assessment [5]

## Results

Two subjects (5 & 8) withdrew from the study and two subjects (6 & 7) were unable to perform the over ground walking assessments during any of the study periods. Of the remaining ten subjects, six (1, 2, 4, 12, 13 & 14) were unable to perform the over ground walking assessments for the baseline period. Ten subjects (five AB and five BA) were able to perform the walking assessments on at least one occasion.

All subjects increased their walking speed on the treadmill over the intervention period. There was a mean increase of 0.175 m/s in the AB group ( $p = 0.001$ , CI = 0.116 to 0.234 m/s) and 0.145 m/s in the BA group ( $p = 0.011$ , CI = 0.049 to 0.240). All subjects also showed improvement in distance walked on the treadmill. The AB group improved by 327.3m on average ( $p = 0.004$ , CI = 165.0 to 489.6 m), while the mean increase in the BA group was 261.2m ( $p = 0.008$ , CI 103.2 to 419.2m). These increases were accompanied by a progressive decrease in the percentage partial weight bearing support. Nine subjects progressed sufficiently to be able to walk on the treadmill assisted by FES but with no additional help from the investigators. Three subjects required some assistance with foot placement and weight bearing from the investigators as well as FES throughout the intervention period.

Figure 2a shows that six of the eight subjects who were able to perform the over ground walking assessments for at least two of the study periods showed a greater increase in over ground walking endurance following treadmill training compared to the control period. This was particularly evident for the AB group. In the BA group the mean increase due to the control and intervention periods was of similar magnitude. All subjects in the AB group, and subjects 9 and 11 in the BA group made larger gains following treadmill training. A similar pattern was evident in the results for over ground walking speed. There were greater increases in walking speed following treadmill training in all subjects in the AB group and for one subject (11) in the BA group (Figure 2b). In subjects who underwent a BA treatment sequence over ground cadence decreased following the control phase (Figure 2c). There was a tendency for the decrease in cadence to be accompanied by increased over ground stride length (Figure 2d) and increased walking speed.

## Discussion

This is the first report of the combined use of PWBS treadmill training and FES in acute ISCI subjects. The customised PWBS system enabled the subject to be supported safely over the treadmill and the additional anterior and posterior attachments prevented lateral sway eliminating the need for a therapist to stabilise the pelvis. Nine subjects did not have the ability to participate in gait training activities prior to the intervention period. However, they were all able to begin treadmill training immediately.

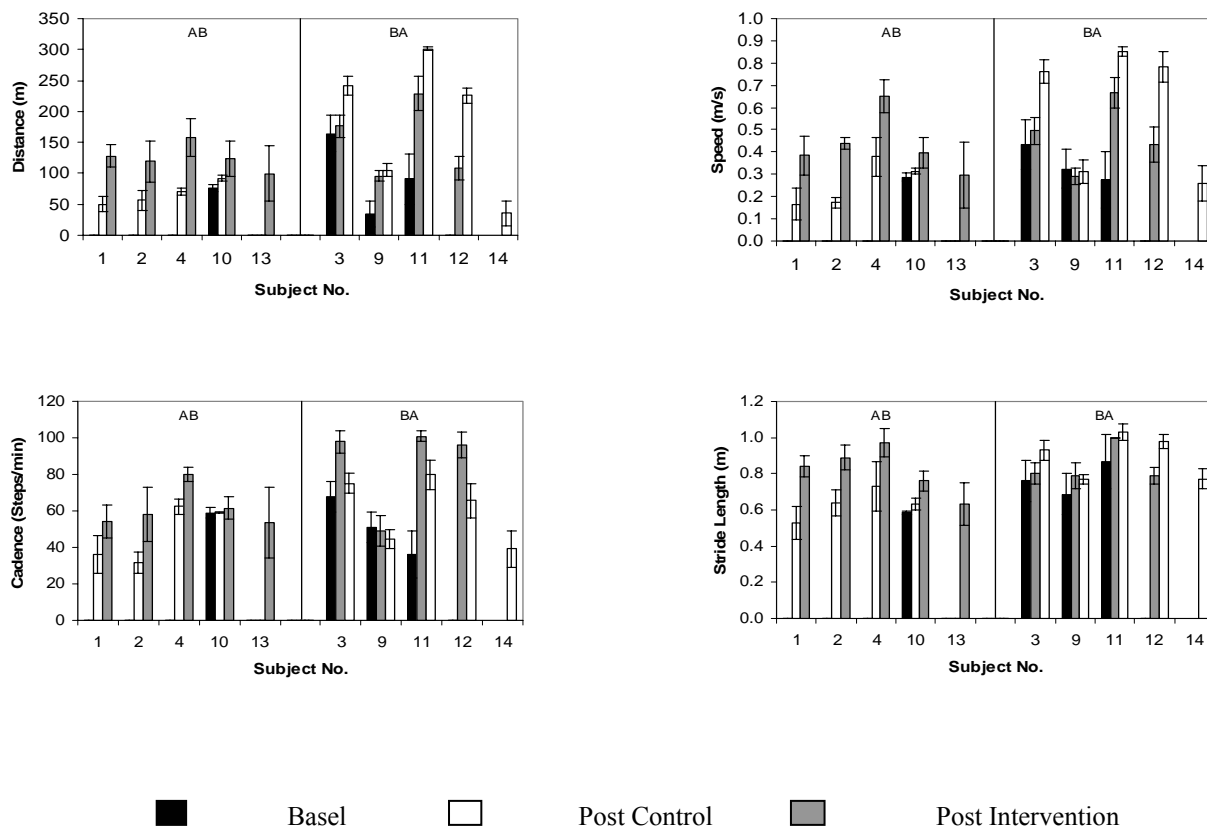


Figure 2 Mean values for over ground gait outcome measure for each study period for all subjects who participated in walking assessments. a) Walking endurance b) Speed c) Stride length d) Cadence. Subjects are grouped into those who received a control – intervention (AB) treatment sequence and those who received an intervention - control (BA) treatment sequence. Note that the order of the columns has been adjusted to correspond to the treatment sequence. n=5 for each subject in each study period with the exception of the post control assessments for Subject 12 where n=2. Vertical bars indicate +/- one standard deviation.

Greater increases in over ground walking endurance and speed were observed following FES and PWBS treadmill training when compared to standard physiotherapy. The random allocation of subjects into AB and BA groups suggested that these improvements were at least part due to the intervention and not solely to natural recovery in this small sample. Conventional gait training techniques are still essential in the transition from treadmill walking to over ground walking to enhance gait quality and teach the use of walking aids.

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