THE COMPUSTIM 10B IN STROKE: CONTROL ALGORITHMS AND PATIENT SELECTION CRITERIA

Wright PA[1], Burridge JH[1], Ewins DJ[2], Mann GE[1], McLellan DL[3], Swain ID[1], Taylor PN[1] and Wood DE[1]

[1]*Address for correspondence:* Department of Medical Physics and Biomedical Engineering, Salisbury District Hospital, Salisbury, Wiltshire SP2 8BJ, UK

[2]Biomedical Engineering Group, School of Mechanical and Materials Engineering, University of Surrey, Guildford, Surrey GU2 5XH, UK

[3]Rehabilitation Research Unit, University of Southampton, Southampton General Hospital, Tremona Rd, Southampton, SO16 6YD, UK

ABSTRACT

The aim of this study was:

- To identify patients most likely to benefit from two channel lower limb stimulation with the microcontroller based Compustim 10B stimulator
- To investigate the orthotic and re-education effects of using a second channel of stimulation
- To develop a database of control algorithms for walking

Fourteen subjects (mean age 63.2, SD 6.7 yrs, 9 Male 5 Female) were recruited who had been treated with the single channel Odstock Dropped Foot Stimulator (ODFS) for a minimum of 6 months. All subjects followed a CONTROL — TREATMENT — CONTROL study design where the TREATMENT was two channel stimulation with the Compustim 10B and CONTROL was single channel common peroneal stimulation with the Compustim 10B. Walking speed and Physiological Cost Index were measured at approximately four-weekly intervals throughout the study. Gait analysis was performed at weeks 0, 12, 24 and 36.

A comparison of clinical observations and the results of gait analysis will be presented.

KEYWORDS: FES, Stroke, Gait, Two Channel

INTRODUCTION

Dropped foot following stroke may be corrected by electrical stimulation of the common peroneal nerve during the swing phase of the impaired leg. Significant improvements in walking speed and effort of walking have been demonstrated in a randomised controlled trial of the single channel ODFS [1, 2].

However, some patients still experience problems through weakness or inadequate control of further muscle groups in the leg. Preliminary work showed that stimulation of an additional lower limb muscle group would improve gait; in particular stimulation of the hamstrings muscle to improve knee flexion during the swing phase of gait and of calf muscle during push-off.

STIMULATOR

A microcontroller based two channel stimulator has been developed [3]. Footswitches underneath the heel and first metatarsal head enable the microcontroller to identify specific stages of the gait cycle. Stimulator algorithms, which included initiation and termination conditions, frequency, and pulse width, were programmed via a user friendly LabVIEW interface [4]. The interface features a real time display of footswitch condition and stimulator output level, which is useful in setting up subjects.

STUDY DESIGN

The study design for all subjects was CONTROL (12 weeks, single channel Compustim) — TREATMENT (12 weeks, two channel Compustim) — CONTROL (12 weeks, single channel Compustim).

The second muscle group for stimulation was selected by clinical observation of each subject's gait. Subjects observed to have poor 'push off' were selected for calf stimulation. Three different algorithms were used for hamstring stimulation:

- on initial floor contact to control knee hyperextension
- during the terminal third of stance phase to limit knee hyperextension at this point and, in addition, to assist forward movement of the knee over the forefoot and thus allow push-off
- during swing phase to enhance knee flexion (probably through quadriceps inhibition)

Two patients were observed to have been suitable for either calf or hamstrings stimulation.

Walking speed and Physiological Cost Index were measured at approximately four-weekly intervals throughout the study. Gait analysis was performed at weeks 0, 12, 24 and 36. This data will be used to investigate the orthotic and re-education effects of using the second channel of stimulation.

Subjects were given a questionnaire to complete on their use of the single channel ODFS before the start of the trial. Subjects were asked to complete a second questionnaire at the conclusion of the trial on their use of the Compustim 10B.

RESULTS

Group receiving Calf Stimulation at Week 24 (n=6)		
No stimulation	1 Channel stimulation	2 Channel stimulation
+9% *(0.03)*	+16% *(0.00)*	+25% *(0.00)*
Group receiving Hamstrings Stimulation at Week 24 (n=6)		
No stimulation	1 Channel stimulation	2 Channel stimulation
+12% *(0.13)*	+15% *(0.08)*	+20% *(0.03)*

Table 1. Percentage increase in walking speed at end of TREATMENT period (Week 24) compared to walking speed measured with no stimulation at beginning of CONTROL period (Week 0). P-values of paired t-tests are shown in brackets.

Results are not yet complete, as not all patients have finished the study at the time of writing. LabVIEW routines are being set up to analyse gait and present data.

Measurements of walking speed and physiological cost index for walking with no stimulation at the beginning of the first CONTROL period have been compared with those for no stimulation, common peroneal stimulation, and two channel stimulation at the end of the TREATMENT period. There were no significant changes in the effort of walking both with and without stimulation for both the group receiving hamstrings and for the group receiving calf stimulation ($p>0.10$, two tailed t-test). There were significant increases in speed observed in both groups (table 1). This confirms our preliminary findings that walking with two channel stimulation is more efficient than walking without stimulation or with just common peroneal stimulation. Graphs are shown of the percentage average increase in walking speed (compared to walking speed with no stimulation at week 0) throughout the study for the group with hamstrings stimulation and for the group with calf stimulation (figures 1 & 2).

Nine patients have completed end of trial questionnaires to date. All respondents reported that they were able to walk further, faster and with less effort with the Compustim 10B. Quality of walking, and confidence and independence in walking, were also improved in all cases. All patients chose to continue using the Compustim 10B at the end of the trial. The main reason for their choice was that the Compustim 10B was more effective in improving walking. The stimulator was considered too large to wear comfortably. Development in minimising the stimulator to a more comfortable size is now underway in response to this observation. Initial problems relating to footswitch reliability were addressed by improving construction techniques and detection algorithms.

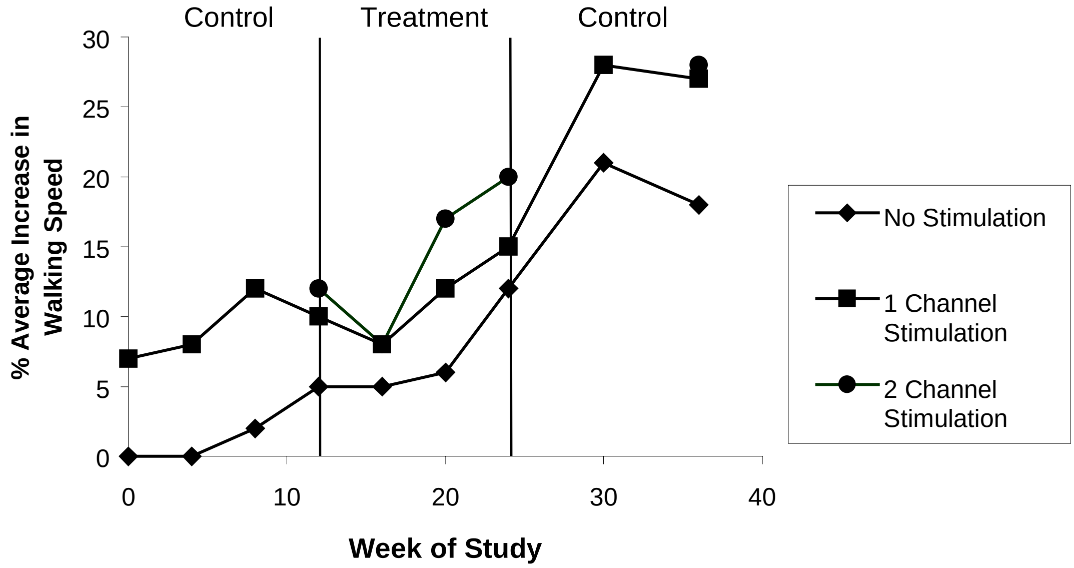

Figure 1. Percentage average increase in walking speed throughout study for patients who received a second channel of hamstrings stimulation (n=6). 95% confidence intervals for each data point are between 5 and 15% but are not displayed for clarity.

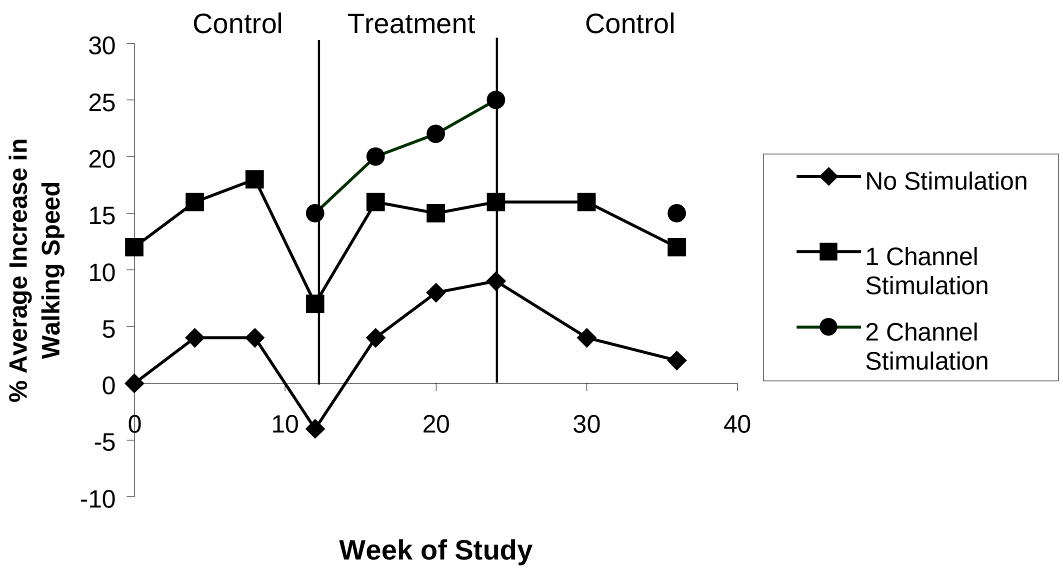

Figure 2. Percentage average increase in walking speed throughout study for patients who received a second channel of calf stimulation (n=6). 95% confidence intervals for each data point are between 5 and 15% but are not displayed for clarity.

DISCUSSION

The group with hamstrings stimulation showed a different pattern of improvement from the group who received calf stimulation. There was evidence of a re-education effect of two channel stimulation in the group receiving hamstrings stimulation but this was less obvious in the group receiving calf stimulation. Both groups demonstrated that walking was improved by single channel stimulation and further improved by either second channel of stimulation. Both groups also showed an orthotic benefit from the second channel of stimulation which increased with the length of time they had used the second channel.

Gait analysis comprised measurement of joint positions and velocities, force plate measurement of ground reaction forces, and EMG studies. Indices are being calculated from this data, e.g. coactivation indices from calf and Tibialis Anterior EMGs, muscle contraction envelopes and timings, and peak forces of Ground Reaction Vectors. These enable investigation of both the orthotic and possible re-education effects of using the second channel of stimulation. Results of gait analysis will be used to consider the importance of gait analysis in the context of selecting and setting up a second channel of stimulation. A list of indicators for selecting patients and setting up patients will then be developed for future use of the Compustim 10B in clinical and research environments.

ACKNOWLEDGEMENT

This work is funded by Action Research. We would like to thank Malcolm Burnett for technical support during gait analysis sessions.

REFERENCES

1. Burridge JH, Taylor PN, Hagan SA, Wood DE, Swain ID. *The Effects of Common Peroneal stimulation on the effort and speed of walking.* Clinical Rehabilitation vol.11, pp201-210, 1997

2. Burridge JH, Taylor PN, Hagan SA, Wood DE, Swain ID. *Common Peroneal Stimulation for the Correction of Drop-Foot.* Report on the Development and Evaluation Committee of the South and West Health Authority (UK), 1995

3. Michael P. *Developments in Surface Electrical Orthoses for the Re-education of Hemiplegic Gait*. PhD Thesis, University of Surrey, 1996.

4. Ewins DJ, Wright PA, Burridge JH, Mann GE, Swain ID, Taylor PN and Wood DE. *The Compustim 10B Programming Interface*. Proceedings of IFESS '99, Sendai, Japan, 1999.