

# PRELIMINARY FINDINGS OF A STUDY OF THE EFFECT OF FUNCTIONAL ELECTRICAL STIMULATION ON THE GAIT OF CHILDREN WITH CEREBRAL PALSY

Stevens CHH, Durham S\*, Eve L\*\*, Ewins DJ  
Biomedical Engineering Group, University of Surrey, Guildford, UK  
\*Paediatric Physiotherapy, Queen Mary's Hospital, London, UK  
\*\*One Small Step Gait Laboratory, Guy's Hospital London, UK

## Abstract

The study attempts to find out if Functional Electrical Stimulation using a single channel dropped foot stimulator on tibialis anterior, with timing controlled by a foot switch can help children with cerebral palsy who walk with a toe gait.

Baseline kinematic and other data of their usual gait was taken using a computerized motion analysis system.

Data collection was repeated at the start and end of stimulation, and after three months of no stimulation. Mean heel - toe intervals of the affected leg rose from 4 to 78 ms in the child analysed. Questionnaire responses by children and parents cite improvements in heel strike in gait, standing with flat feet, toe clearance during swing phase and increased stability.

## Introduction

Persistent toe walking in children with cerebral palsy may lead to poor balance, frequent falls, greater asymmetry, and likely development of fixed deformity resulting in reduced function.

Accepted current practise to reduce toe walking include orthotics, botulinum toxin, physiotherapy, exercise and surgery [1,2].

An alternative approach is that of electrical stimulation. This has been used for many years in the rehabilitation of muscle activity following neurological damage, e.g. spinal cord injury and stroke [3,4,5]. Considerable work on Functional Electrical Stimulation (FES) has been carried out in adults with hemiplegic gait [6,7]. [6] for example, demonstrated an improvement in walking speed of 10% or more by 12 of the 16 patients receiving FES and a mean reduction in physiological cost index of 33% when electrical stimulation was used as an orthosis. There were also improved scores on quality of life measures.

In comparison, less work has been reported in assisting gait in children with cerebral palsy with electrical stimulation. However, the general view is that although

requiring further work it offers possible therapeutic and functional benefits [8,9,10].

There is conflict in the literature regarding the use of electrical stimulation in children with cerebral palsy. Some evidence supports the use of stimulation to the tibialis anterior muscle, others support stimulation of the calf muscles. In this, the first of two pilot studies, the aim is to quantify the effect of stimulating the tibialis anterior muscle during gait. A second study is planned to investigate the effects of stimulating calf muscles.

## Methods

An ABA approach was used. This study design was thought appropriate to a pilot study with a small sample size. It was not possible to use a placebo or to use double blind studies due to the nature of the intervention. Ethics approval was obtained from the Queen Mary's Hospital (QMH) Trust.

Patients who presented with a toe-walk gait were recruited from existing departmental caseload together with referrals from other departments. Seventeen children were screened for the study. Of these, twelve were recruited (8 boys and 4 girls, with an age range of 6 to 14 years, mean 9 years). To date, all have completed phase A1, five are in phase B, three are in A2, and four have completed the trial.

The selection criteria were:

- Diagnosis of cerebral palsy.
- Walking with toe gait indicated by limited heel contact, increased tripping and falling, typical wear pattern on shoe.
- Had 90 degrees dorsiflexion passively, with knee extended. Checks were also made to discount associated problems, e.g. other contractures and joint problems.
- The child was co-operative, with parents/ carers motivated to carry out programme.
- Tolerant of machine.
- Able to walk independent of aids.

The exclusion criteria were:

- Surgery or Botox injection within 18 months.
- Concurrent use of fixed AFO.
- Insufficient parental/guardian/carer support to use equipment reliably.
- A need for more than single channel stimulation.
- Severe contractures and/or fixed deformities

### **Intervention**

In the first A period (0-3 months), baseline data of the child's gait patterns (with any current orthosis if applicable) were recorded twice at the start of month 1, 1 week apart (session 1 and session 2) and once at 3 months (session 3). Session 1 was used to acclimatise the subject to the gait laboratory and the measurements to be made. Data from this session were not used in the final analysis.

At the start of phase B (3-6 months) the electrical stimulator was set up. Stimulation was applied to the Tibialis Anterior muscle (directly through the motor nerve or through stimulating the flexor withdrawal reflex action), using the Salisbury (Salisbury Hospital, UK) ODFS III single channel dropped foot stimulator. The stimulation envelope timings were adjusted to optimise improvements in the movement of the leg and foot during gait. The foot switch was positioned under the heel or metatarsal head. A follow up took place the next day to ensure that electrical stimulation was being applied correctly. For the three months of this phase the stimulator was to be used throughout the day as a gait assist device, within the confines of the subjects' daily schedule.

The gait measurements were carried out at the follow up (session 4) and end of this phase (session 5). Data were collected with and without stimulation to facilitate investigation of the orthotic and therapeutic effect of stimulation. In addition a patient questionnaire (developed in conjunction with the Clinical Audit Department at QMH) was used after 1 and 3 months of this phase to discover the subjects' usage, compliance and perspective. This phase has not been completed, so a full analysis of all subjects is not yet possible

In the final A period, the electrical stimulation orthosis was withdrawn, with gait data being recorded at the start and end of this phase (session 5 and session 6).

Normal physiotherapy treatment by the child's regular therapist has continued throughout all phases of the programme. Additional monthly checks and telephone contact being offered in case of problems during phase B to ensure correct use of equipment, but with no additional therapy. The gait analysis session (session 5)

at the end of phase B includes measurements needed for the start of phase A2 i.e. gait without stimulation.

### **Data Collection**

Subjects were timed whilst they walked 25 metres with a heart rate monitor (Polar Electro Oy, Kempele, Finland). Heart rate was recorded before and after each walk for three walks to give an estimate of the physiological cost index (PCI).

Passive and active ranges of motion for ankle, knee and hip joints were measured using an electric goniometer (Biometrics Ltd, Cwmfelinfach, UK).

Subjects stood on a dual 3.3 metre long force platform [11] with one foot on each platform to record their weight distribution in the standing trials. Subjects then walked over the platform for the walking trials, from which kinetic and spatio-temporal data were obtained

Sagittal and frontal plane video were recorded onto tape and displayed using a split screen TV monitor. The video record was employed to aid in the analysis of the kinematic data.

Retroreflective markers were attached to the left and right acromion processes, sacrum, left and right asis, thighs, lateral epicondyles, shanks, and at the level of the lateral malleoli and third metatarsals (modified Helen Hayes). The coordinate data of the markers for standing and walking were collected using a six camera Mac Reflex 60Hz system (Qualisys AB, Partille, Sweden).

A record of the marker positions for each session was made using frontal, rear, left and right photographs.

### **Data Analysis**

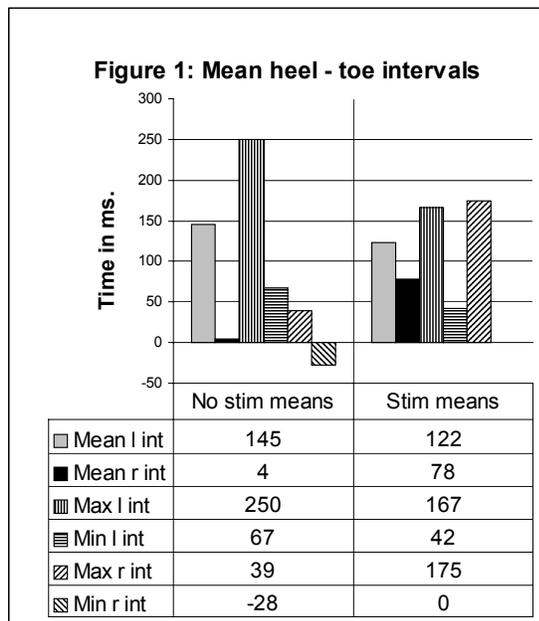
Measuring the heel-toe interval tells us how often the heel reaches the floor and in what sequence relative to the toe. This paper reports on data from one subject for phases A1 and B.

Using data collected in standing for the ankle and toe markers, the z-coordinates of these markers at heel and toe contact were found. These values were used as thresholds to estimate the timings of heel and toe contact in the walking data. 103 steps of the no-stimulation condition and 74 steps of the with-stimulation condition were analysed in this way. The mean, maximum and minimum intervals between heel and toe contact for each condition were calculated.

Other analyses underway include step length, degree of knee flexion at heel contact, PCI, and walking speed with heel contact.

## Results

Figure 1 is a graph and table, which shows the mean heel-toe contact interval (int) for one subject, whose right leg was stimulated, for the no-stimulation and stimulation conditions for the left (l) and right (r) feet. Also it shows the maximum and minimum heel-toe intervals.



Questionnaire returns of the orthotic effect and acceptability so far include improvements in heel strike in gait, standing with flat feet, toe clearance during swing phase and increased stability.

## Discussion

The analysis presented suggests the efficacy of FES in the case considered. Analysis of a wider range of data detailed above from all the children in the study is underway.

The additional monthly checks in phase B were necessary to ensure correct use of the equipment. Although no therapeutic input was intended, it is recognised this may result in a bias in the results.

## References

- [1] Cosgrove AP, Corry IS, Graham H. (1994) Botulinum toxin in the management of the lower limb in cerebral palsy. *Develop Med and Child Neurol*, 36, 386-396.
- [2] Fulford GE, Brown JK. (1976) Position as a cause of deformity in children with cerebral palsy. *Develop Med and Child Neurol*, 18, 305-314.

[3] Bajd T, Kralj A, Karcnik T, Savrin R, Obreza P. (1994) Significance of FES assisted plantar-flexion during walking of incomplete SCI subjects. *Gait and Posture*, 2:5, 5-10.

[4] Bogataj U, Kljajic M, Gros N, Acimovic R, Malezic M, Stefan J. (1993) The rehabilitation of gait in stroke patients: a comparison between conventional therapy and multichannel neuromuscular electrical stimulation therapy. *The Ljubljana FES Conference*, Ljubljana, Slovenia,

[5] Ewins DJ, Taylor PN, Crook SE, Lipczynski RT, Swain ID. (1988) Practical low cost stand/sit system for mid thoracic paraplegics. *J Biomed Eng*, 10:2, 305-314.

[6] Burrige J, Taylor P, Hagan S, Swain I. (1997) The effect of common peroneal stimulation on the effort and speed of walking. a randomised trial with chronic hemiplegic subjects. *Clinical Rehab*, 11:3, 201-210.

[7] Granat MH, Ferguson ACB, Andrews BJ, Delargy M. (1993) The role of functional electrical stimulation in the rehabilitation of patients with incomplete spinal cord injury – observed benefits during gait studies. *Paraplegic*, 31, 207-215.

[8] Carmick J. (1995) Managing equinus in children with cerebral palsy: electrical stimulation to strengthen the triceps surae muscle. *Develop Med and Child Neurol*, 37, 965-975.

[9] Comeaux P, Patterson N, Rubin M, Meiner R. (1997) Effect of neuromuscular electrical stimulation during gait in children with cerebral palsy. *Pediatric Physical Therapy*, 9, 103-109.

[10] Hazlewood ME, Brown JK, Rowe PJ, Salter PM. (1994) The use of therapeutic electrical stimulation in the treatment of hemiplegic cerebral palsy. *Devel Med and Child Neurol*, 36, 661-673.

[11] Hynd D, Hughes SC, Ewins DJ. (2000) The development of a long, dual platform triaxial walkway for the measurement of forces and temporal-spatial data in the clinical assessment of gait. *Proc Instn Mech Engrs*, 214, H:193-201

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