Upper and Lower Limb Electrical Stimulation in Paediatrics
Held at Queen Mary’s Hospital, Roehampton, London
Thursday, 13th June 2002

The aim of the workshop was to promote discussion and the exchange of ideas in an informal setting. There were eight presentations covering many aspects of upper and lower limb stimulation. These were followed by an open discussion.

The workshop confirmed that there is considerable interest in stimulation for the paediatric patient group, but that uptake is limited by the lack of assessment/prescription guidelines and clinically relevant outcome measures.

David Ewins

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Lower limb FES for CP Children: A Review of Published Papers
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FES has been used for many years in the rehabilitation of muscle activity following neurological damage in adults, e.g. spinal cord injury and stroke. As a result of these studies, it has been suggested that the dynamic nature of FES may promote more normal gait and that FES also has the potential to strengthen and re-educate the affected muscles.

In comparison, less work has been reported in assisting gait in children with cerebral palsy using electrical stimulation. Furthermore there are two apparently opposing approaches with some studies reporting positive results from stimulating the anterior tibial muscles. Other studies report positive results due to stimulating the calf muscle.

The rationale for electrical stimulation of the anterior tibial muscle is to produce active dorsiflexion at the ankle during the swing phase of gait, which at the same time reciprocally inhibits the antagonist, triceps surae. In contrast, stimulating the triceps surae is thought to favourably modify altered muscle activation patterns with a reduction in spasticity.
Upper Limb impairment is a major handicap to many children with Cerebral Palsy (CP). It may make activities of daily living, sitting, balance, and maintaining personal hygiene difficult or impossible without assistance. The existing management techniques of surgery, physiotherapy, orthoses and medication are not always the answer and so the application of Functional Electrical Stimulation (FES) for the upper limb of children with CP has recently been considered.

Atwater et al. (1991) published the first report on the application of FES to the upper limb of children with CP. Two children, aged eleven and twelve years, were given three wrist extensor stimulation sessions of 20 minutes duration each week for eight weeks. Active wrist extension range of motion (ROM) and the time taken to carry out some functional grasp and release tasks were recorded pre-treatment and immediately post-treatment. No significant changes in ROM were recorded. The time taken for the children to complete the hand function tests decreased although the time taken for a group of children not receiving upper limb stimulation to complete the same tasks decreased by a similar amount.

In subsequent case studies by Carmick (1993b, 1997) investigating FES as a treatment for the upper limb of children with CP several qualitative observations were made following treatment. These included improved weight bearing with the impaired upper limb, increased awareness and spontaneous use of the impaired limb and improved hand grasp and release abilities. This work by Carmick suggested that FES could improve hand function and ROM. These were
qualitative observations, however, and there was little quantitative evidence to support them. Schecker et al. (1999) reported on 19 children and young people (aged 4 to 19 years) who used a combination of electrical stimulation and dynamic bracing to reduce upper extremity spasticity. Two thirty-minute sessions of extensor stimulation combined with dynamic orthotic traction for between 3 and 43 months was given. A static brace was used at night. Spasticity improved by between 1 and 3 levels on the Zancolli classification system for all patients. Wright and Granat (2000) investigated the effect of cyclic FES on the wrist extensor muscles of a group of eight children with hemiplegic CP (mean age 10 years, 5M 3F). The study design was baseline (three week) – treatment (six week) – follow up (six week). FES was applied for 30 minutes daily during the treatment period of the study. Improvements in hand function \( (p<0.039) \), and active wrist extension \( (p=0.031) \) were observed at the end of the treatment period. These improvements were largely maintained until the end of the follow-up period. No significant change was observed in the measurements of wrist extension moment during the treatment period \( (p=0.274) \).

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Study of the Effect of Functional Electrical Stimulation (FES) on walking in children undergoing Botulinum Toxin A therapy

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Children with neurological disorders such as cerebral palsy exhibit an abnormal gait mainly due to the loss of selective motor control and spasticity. It has been shown that spasticity can be controlled by using botulinum toxin A. The deactivation of the spastic muscle gives an opportunity for the inactive muscle to be activated. But due to the lesion in the motor cortex the child’s ability to initiate movement in the inactive muscle is very poor. We propose that FES can be used to activate specific inactive muscles.

The aim of this study is to determine the feasibility of using FES for correction of abnormal gait pattern in children who are undergoing botulinum toxin A therapy. Long term application of FES will be used to determine if this would improve the movement pattern.

The subjects are being recruited from the pediatric neurology clinic at Yorkhill Hospital, Glasgow. Subjects will be within the age range of 4-8 years and have gait deviations due to dynamic equinus. The study will involve between 12-15 subjects, with the first 2 or 3 subjects participating in a pilot phase. The FES training involves two phases, each lasting for a period of four weeks. The testing procedure to measure the outcome of the FES integrated training includes gait, electromyography (EMG) and video analyses. Each subject would be participating in the study for twenty weeks.
The combined gait and EMG analyses are carried out to reveal the biomechanical and physiological changes that take place in the muscles undergoing FES. The outcome of this study would demonstrate the feasibility of using FES to improve movement patterns.

The Effect of Functional Electrical Stimulation on the Gait of Children with Cerebral Palsy: a pilot study
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Abstract
Equinus foot disorder (toe walking) is a common problem for patients with cerebral palsy who are able to walk. Functional electrical stimulation is a recommended method of improving foot drop in adult stroke patients. The efficacy of functional electrical stimulation to the anterior tibial muscles was evaluated in a pilot study of 10 children with cerebral palsy who walked with a toe gait. The mean age of the children was 9.1 years.

Electrical stimulation was set up as a functional orthosis with a pressure switch under the heel to time the stimulation of the anterior tibial muscles at the appropriate time in the gait cycle. The outcome was evaluated using three-dimensional instrumented gait analysis. The primary outcome measure was heel-toe interval. Secondary outcomes were walking speed, step length and knee angle at initial contact and physiological cost index of gait. Joint range of motion at the ankle, height and weight were recorded, and user perspective investigated by questionnaire.

These parameters were determined on setting up the stimulator, after three months of use and three months after discontinuing use.

Descriptive statistics for the whole group suggest an immediate (orthotic) benefit in heel-toe interval and reduction in energy expenditure, but little therapeutic benefit. However, the detailed analysis suggests that some of the children had a better response to stimulation. Reasons for this are being investigated.
Results suggest that functional electrical stimulation to the anterior tibial muscles for this population of patients may be a useful intervention. Further work is needed to develop more lightweight and cosmetic equipment, and refine selection criteria.

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Functional and Therapeutic Electrical Stimulation in Children: an evaluation of the clinical work at Salisbury District Hospital (1996-2002)
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Introduction and Aims
The Functional Electrical Stimulation (FES) Clinic was established at Salisbury District Hospital in 1996 as a National Health Service clinic. Paediatric referrals have comprised 5% of the total number of patients seen to date. A review of the service to children was planned with the aim of evaluating clinical effectiveness.

Salisbury FES Clinical Service
The children seen to date have used both therapeutic exercise stimulation (TES) and functional electrical stimulation at the clinic. TES has been used to strengthen the stimulated agonist, to improve passive soft tissue length, and to inhibit antagonist spasticity. It has also been used to prepare children for the use of FES, including helping children accommodate to the sensation of stimulation. FES has been used to increase the mobility of children and improve the quality of their gait pattern.

Methods
The review considered the findings taken from the clinical database of the Salsibury FES Clinic, and the medical notes of children seen. Outcome measures used include walking speed and the Physiological Cost Index of gait.
Results and Discussion

Diagnoses

A total of 65 children have been seen to date. Referrals of children with neurological conditions comprise the largest group (97%). The majority of children (68.2%) have cerebral palsy (CP); acquired hemiplegia form the second biggest cohort (18.1%). Importantly, with respect to the range of conditions, a number of orthopaedic referrals (6%) have also responded positively to stimulation, as have children with facial and Erbs palsy.

TES

33 children have participated in a programme of TES to the lower limb. Parameters used include stimulation of the common peroneal nerve, and the calf, quadriceps and gluteal muscles. 18 children have used TES in the upper limb and 2 children used TES to the facial nerve.

FES

29 children have used the single channel Odstock Dropped Foot Stimulator (ODFS). 12 children are full users of the ODFS, where the device is used throughout the day to assist walking. 17 children are partial users, who use the ODFS during the evenings, weekends and during gait re-education sessions. Some cosmetic issues have also been reported.

10 children have used the Odstock 2 channel stimulator (O2CHS): six children stimulating the common peroneal nerve bilaterally; three the common peroneal and calf; one the common peroneal and quadriceps; one the calf bilaterally.

Walking tests used to monitor an individual’s response to stimulation have not been as consistently carried out as in the adult population. Qualitative improvements in walking pattern do not always correlate with increases in walking speed. Individual patient response curves are variable, and there was missing data. Mean scores of the most complete results have been analysed. Walking speed tests have shown an increase of 8% in non stimulated walking at 6 weeks, of 10% at 6 months, and 22% at 12 months. The total orthotic effect at 12 months was 27%.
Conclusions
The benefits that have been demonstrated, and the reported practical and cosmetic problems warrant further study. A debate on the best clinical measures to use with children would also be of value.

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Electrical Stimulation Of The Gluteus Maximus In Children With Cerebral Palsy: Effects On Muscle Strength And Gait Characteristics
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Introduction
Electrical stimulation (ES) has been suggested as a treatment to increase muscle strength, range of motion and motor function in cerebral palsy (1,2). The aim of this study was to investigate whether ES to the gluteus maximus would improve muscle strength, gait characteristics and motor function of children with cerebral palsy.

Patients and Methods
Twenty-two children (aged 5-14) with cerebral palsy and no previous surgery to the hips were recruited. Each child was matched with another child on age, estimated hip extensor strength and internal hip rotation in gait. The children of each pair were then randomly allocated to either the ES or the control group. All children in the study continued with their normal physiotherapy sessions and home exercises. Surface stimulation was applied using the NeuroTrac 2 stimulator to the most affected leg. The parents were asked to apply the stimulation 6 days a week for one hour a day. The first two weeks were used to familiarise the child with the sensation and to condition the muscle using a low intensity and low frequency (10Hz) stimulation. In the remaining 6 weeks the stimulation frequency was 30Hz, the pulse width 100 ms, with a 5-10s on-off cycle and 0.8 ramp at both sides of the stimulation period.
The following pre and post test measurements were taken for all children: 3D gait analysis, strength of the gluteus maximus measured using the MIE Myometer, passive range of movement of the hips and Section E of the GMFM. The parents of the children in the stimulation group were given a questionnaire on the use of the electrical stimulator. The differences between the measurements taken in the first and second assessment were compared between the stimulation and control group using paired t-tests (p<0.05).

**Results**

In most of the children a good visible contraction of the gluteus maximus was achieved. The majority of the parents thought the stimulator was easy to use and only two children disliked using the stimulator. Subjectively, seven parents thought that the treatment made a difference to their child. However, no significant objective differences were found between the ES and control group for GMFM score, walking speed, muscle strength, peak internal rotation and peak hip extension in gait or passive limits of hip rotation, passive hip extension and femoral anteversion.

**Discussion**

No significant effects of ES to the gluteus maximus on the any of the measurements taken were found. One possible explanation is that the gluteus maximus has more muscle mass than for example, the tibialis anterior where ES has proven successful (1). It was therefore more difficult to stimulate the whole muscle without discomfort. Further, the external rotation of the hip in prone lying or sitting as triggered by ES in this study is considerably different from the function of the gluteus maximus during gait. It has been suggested (3) that electrical stimulation is more successful when the movement achieved by stimulation is more functional.

**Conclusion**

This study did not support the use of electrical stimulation to the gluteus maximus, using this protocol, as a treatment option for children with cerebral palsy in order to improve muscle strength, gait characteristics or motor function.
REFERENCES

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Functional Electrical Stimulation (FES) to improve Gait in Cerebral Palsy
A Case Study
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Background
G. is a 12 year old boy with cerebral palsy, referred to the Salisbury Medical Physics department in February 2000 for FES assessment to improve gait. He has an asymmetrical diplegic gait with a greater degree of flexion and internal rotation of the right leg. Plaster casting and night splinting have been used to treat shortening of the lower limb tendons. These produced little improvement. Ankle-foot orthoses (AFOs) were subsequently prescribed. Future surgery has been proposed.

Initial Assessment
Muscle weakness in the lower limb was greater on the right than the left. G. walked quickly with bilateral toe strike and knee flexion on initial contact. The right hip was weak and flexed, adducted and internally rotated. Hip ‘hitching’ during swing phase allowed the foot to clear the ground. G. achieved heel strike only when wearing the AFOs. Both feet were inverted. He was able to walk ½ a mile without a walking aid. Initially, G. was sensitive to the sensation of the stimulation and unable to tolerate the intensity necessary to produce muscle contraction.
**Treatment**

G. used an exercise stimulator for 8 weeks to stimulate the right common peroneal nerve, in order to reduce his sensitivity to the sensation of stimulation. At the end of this period the Odstock Dropped Foot Stimulator (ODFS) was set up successfully. G. had also stopped using his AFOs because of blistering on both feet. His usual toe walking pattern was improved by stimulation achieving a neutral flat foot position with occasional heel strike. G. was able to improve his gait pattern still further with conscious effort. He wore the ODFS daily and carried out exercise stimulation once a day. After 6 weeks his walking speed increased by 2% and effort reduced by 39.3%. After 9 months using both the ODFS and exercise stimulation G. continues to toe walk without stimulation and does not gain consistent heel strike unless he concentrates on doing so. His walking pattern is improved by stimulation and is less effort. However, poor alignment at the trunk and hip compound his walking problems.

G. is now growing rapidly. Recently, his mother reported that his hamstrings were becoming tighter and that G. was weight bearing on a very flexed right knee. A second channel of stimulation for the right quadriceps was tried in the clinic with good response. This has not yet been set up for G. to use at home as it remains to be seen whether the optimum second channel is the quadriceps or the gluteal muscles. The latter may allow the hip to be aligned so that greater stability and more effective use of the knee extensors during stance are possible. This will be discussed video evidence presented of the effect of stimulation on G’s walking pattern.