CORRECTION OF BI-LATERAL DROPPED FOOT USING THE ODSTOCK 2 CHANNEL STIMULATOR (O2CHS)

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ABSTRACT

A single dropped foot can be successfully corrected using a single channel stimulator controlled by a foot switch. When an individual has bilateral dropped foot using two independent devices presents the difficulty that both channels can be active simultaneously, putting the user in an unstable situation. The O2CHS is a two channel device which can be controlled by one or two foot switches. The sequence of stimulation can be selected using internal switches and trimmer controls. For Bilateral dropped foot a single heel switch is used, channel 1 is triggered by heel rise and ended by heel strike. Channel 2 is triggered by heel shrike and ended by heel rise. For all but the fastest walker it was found necessary to add a short delay between the channels, after heel strike.

Performance with the device was measured using walking speed and physiological cost index (PCI). Twenty subjects used the device (11 multiple sclerosis, 2 spinal cord injured, 1 stroke, 1 cerebral palsy and 5 with other spinal pathologies) of mean age 50.4 years. There was a mean increase in speed of 22.4% (p=0.022) and reduction in PCI of 12.2% (p=0.018) when the O2CHS was first used. For more able users, use of the device enables greater distances, reducing the risk of falling due to tripping. For the less able it enables mobility over short distances, delaying final dependence on the wheelchair.

INTRODUCTION

Bilateral dropped foot is common as a result of multiple sclerosis, incomplete spinal cord injury and some forms of stroke. The condition significantly impairs mobility and is often not well corrected by orthotic devices. Dropped foot can be successfully corrected using a dropped foot stimulator, controlled by a foot switch placed in the shoe. Generally, stimulation of the common peroneal nerve begins at heel rise and continues until the heel is placed back on the ground. Such a control strategy presents difficulties if the subject has bilateral dropped foot, as it is possible to stimulate both common peroneal nerves at the same time leading to instability.

The Odstock 2 Channel Stimulator (O2CHS) is designed to be operated by a single foot switch, simplifying the practical application of the device and ensuring that only one channel of stimulation is possible at a time. This paper presents the stimulator and changes in walking speed and physiological cost index (PCI) when it is used.

THE O2CHS

The O2CHS is a development of the Odstock Dropped Foot Stimulator (ODFS)\textsuperscript{2,3,4} which has been used extensively in the UK. It is of discrete logic design, implemented in surface mound technology. Control of the device is state driven using force sensitive resistor based foot switches as
inputs. The switch input system is self-calibrating allowing the switches to be used with a heavy adult or small child without adjustment and automatically adapting to drift in foot switch resistance. Parameters are selected by adjustment of trimmer controls and switches, which while it does not lead to the elegance of other high tech computer-based systems, it does allow a small, stand-alone unit at a reasonable cost. Evan so a large number of control strategies are available. The device is CE marked.

The device can be considered as two dropped foot stimulators in one box. Each channel can be triggered by either release or application of pressure to its foot switch. Additional logic controls the interaction between channels, allowing both channels to be controlled by one switch or one channel to be started by one switch and ended by the other. The output can be active either for a fixed time or adaptive to the foot switch up to a maximum time out time. At the end of the simulation time a fixed extension time can be set delaying the end of the output. This is typically used to extend the output after heel strike to prevent the forefoot rapidly striking the ground after heel strike when correcting dropped foot. Ramps can be set independently at the beginning and end of each output. Additionally, channel two has a pre-output delay so it's output can be used to stimulate muscles at times that do not coincide with foot switch state changes. The time out function in adaptive timing can be disabled to allow continuous output. This is used for quadriceps stimulation to provide knee extension for as long as pressure is maintained on the heel switch.

For bilateral dropped foot correction, a single foot switch is used. This reduces the number of cables used and also ensures that only one channel can be active at one time. With the foot switch placed under the heel of the side of channel 1, stimulation of channel 1 begins when the heel is lifted from the ground and continues until the heel is returned to the ground. For the majority of users there follows a short delay followed by stimulation from channel 2 to the other side. Channel 2 is ended by heel lift and the cycle repeats. The stimulation is ramped at the beginning and end of each output to improve the comfort of the stimulation and reduce the activation of stretch reflexes in the calf muscles due to sudden stretching. Stimulation is at 40Hz 300_s with currents up to 80mA.

The active electrode is placed over the common peroneal nerve as it passes over the head of the fibula bone and the indifferent over the motor point of the anterior tibialis muscle. When a greater withdrawal reflex is required, the indifferent electrode may be placed over the nerve as it passes along the lateral boarder of the popliteal fossa. Pals Plus skin surface, self-adhesive electrodes are used.

**TREATMENT**

Two clinic appointments were made on consecutive days for fitting of the O2CHS. On the first day the stimulator was set up and its use explained to the user. On the second day the patient was asked to attend wearing the device so the clinician could assess the patient's ability to set up the device independently. Further adjustments were made and training given as necessary. Patients were followed up 6 weeks later, a further 3 months later and then every 6 months whilst they continued to use the stimulator. When setting up the stimulator for the first time, great emphasis is put on training the user, and their carer if appropriate, to correctly identify the movement produced by the stimulation and techniques used to modify it by changing the electrode positions. Instructions are also given in written form. The exact electrode position may vary from day to day, possibly due to the varying amounts of calf tone.

**SUBJECT SELECTION**

All patients were referred by their consultant or general practitioner and assessed for their suitability for treatment at an assessment clinic. Patients were judged to be suitable for treatment if they had a bilateral dropped foot, which was due to an upper motor neurone lesion and was corrected by electrical stimulation. 6 subjects (5 multiple sclerosis and 1 stroke) initially received a single dropped foot simulator but were transferred to a bilateral stimulator after their condition changed. Patients were able to move from sitting to standing unaided and be able to walk at least 10 metres with appropriate aids. Patients had to be able to have at least a basic understanding of the
treatment and, if necessary, have access to assistance from a carer. Tolerance of the sensation of the stimulation was essential.

Walking speed and Physiological Cost Index (PCI), which is an indication of the amount of effort in walking, were obtained, concurrently. The patients were asked to "walk briskly" on linoleum over a 10 metre (m) course with 1m at either end for acceleration and deceleration. Patients normally walked this course three times with stimulation and three times without. The order of stimulation / non-stimulation was randomised to compensate for any fatigue. The mean speed and PCI for stimulated and non-stimulated walking was calculated. Occasionally, some patients were not able to complete six lengths of the course so fewer "runs" were recorded.

RESULTS

Twenty subjects used the O2CHS. 11 subjects had multiple sclerosis, 2 incomplete spinal cord injury, 1 stroke, 1 cerebral palsy and 5 had other spinal pathologies. The average age was 50.4 years standard deviation 12.6 years, 11 were male, 9 were female. Results which are those recorded at the first assessment, made when the stimulator was first set up, are given in tables 1 and 2. The PCI data is missing one set of data due to difficulty measuring the heart rate of one subject. In order to estimate the clinical significance of the results, the number of subjects who changed their walking speed by greater than 10% has been calculated. A change of less than 10% could be considered to be insignificant to the user.

Table 1

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<th>Speed n=20</th>
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<td></td>
<td>Mean speed without O2CHS (ms(^{-1})) standard</td>
<td>Mean speed with O2CHS (ms(^{-1})) standard</td>
<td>Mean % change in walking speed standard deviation</td>
<td>No. of subjects with greater than 10% increase in walking</td>
<td>No. of subjects with greater than 10% reduction in walking</td>
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<td>0.41 _ 0.32</td>
<td>0.46 _ 0.30</td>
<td>22.4 _ 40.4 p=0.022</td>
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Table 2

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<tr>
<td></td>
<td>Mean PCI without O2CHS (ms(^{-1})) standard</td>
<td>Mean PCI with O2CHS (ms(^{-1})) standard</td>
<td>Mean % change in PCI standard deviation</td>
<td>No. of subjects with greater than 10% reduction in PCI</td>
<td>No. of subjects with greater than 10% increase in PCI</td>
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<td>2.15 _ 3.04</td>
<td>1.93 _ 2.81</td>
<td>-12.2 _ 15.2 p=0.018</td>
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<td>2</td>
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DISCUSSION

The results show a significant orthotic benefit from using the O2CHS. It's use produced a change of greater than 10% in PCI and walking speed, in half those who used it, indicating a significant gain in mobility. Use of the device often extended the range of users, allowing access where wheelchair access was not possible or leading to the wheelchair being discarded for short transfers from car to office or home. For some users, as their condition progresses, it becomes their only means of achieving walking, delaying final dependence on the wheelchair. The perceived benefit from the device was often greatest in the later group of users, many of who are not included in this study as they are not capable of completing the 10m course without the assistance of the device.
ACKNOWLEDGEMENTS

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REFERENCES.


