



An investigation into the relationship between types of muscle dysfunction and response to common peroneal nerve stimulation

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Correction of dropped foot by Functional Electrical Stimulation (FES) has been reported to be effective, but not for everyone. Even in a sample of enthusiastic, compliant and apparently suitable patients different responses were seen that were presumably of a biological nature.

The immediate effect of FES of the tibialis anterior and peroneal muscles is to act as an orthosis, bringing the ankle into greater dorsiflexion as the foot leaves the ground. At the same time (particularly when the lateral popliteal nerve is stimulated directly) a sensory stimulus is given which can facilitate a flexor withdrawal response in which flexion may occur at both the hip and the knee. In some subjects a second effect is seen termed 'carry-over', in which the gait pattern without stimulation is altered for minutes, hours or, in some cases days after a period or periods of stimulation. (Three trial subjects experienced more than 25% increase in walking speed). This latter effect implies biological functional changes in the connectivity of sensori-motor pathways in the nervous system concerned with gait. The patterns of muscular activity in the lower leg, associated with such changes have not been formally studied.

Knutsson and Richards and Knutsson and Martensson identified three types of motor dysfunction affecting the gait of people with hemiplegia. Our preliminary work has, in general confirmed these observations. Motor dysfunction appears to be a product of inappropriate activation and an inability to activate particular muscle groups, but early results suggest that some patients cannot really be categorised by Knutsson's criteria. We have observed that despite having a drop-foot most subjects exhibit apparently normal activation of the tibialis anterior muscle.

Experiments with healthy subjects have established a range of normal patterns and indices of co-contraction. They have also confirmed that, when the ankle is moved passively at 3Hz no stretch response is observed.

Recordings of EMG, resistance to passive movement and the ability to control a voluntary movement have been used to categorise patterns of impaired muscle activation. Indices of co-activation and of modulation have been derived that quantify inappropriate muscle activity during both passive (stretch index) and active (co-activation index) movement.

Questions

1. Does the classification of motor dysfunction proposed by Knutsson allow all subjects to be categorised or is there a fourth group? (As suggested by our preliminary studies).
2. Can this classification be used to identify:
 - Patients whose gait will be improved during stimulation
 - Patients who will experience carry-over; i.e. an improvement in voluntary control of the ankle following a period of stimulation.



3. Is the pattern of muscle activation in the absence of stimulation altered by a period of stimulation, and are these changes related to the clinical response to FES?

Method of investigation

Subjects were assessed three times over a period of two to three weeks to measure variations in muscle activation and walking prior to using FES. From these measurements each person, was allocated to one of Knutsson's three categories. Any who could not be assigned to these categories was allocated to a fourth category and continued to be studied. It is intended that five or six subjects will be studied in each of the categories (at least five in each of the three Knutsson categories), giving a total of at least 20 subjects.

Our experience has been that most people who benefit from FES generally do so within three months continuous use. The investigation therefore observed changes over this period in a group of people with different patterns of muscle activity.

Patients were observed walking and performing a tracking task in a specially designed rig in which response to passive and active movement were measured. In the active test the patient was asked to follow a tracking signal. In the passive test the operator moved the ankle passively with the tracking signal.

The rig enabled ankle angle and torque about the ankle joint to be recorded simultaneously with EMG signals from the calf and anterior tibial muscles. The tracking signal consisted of a cross corresponding in size with an elliptical target generated by a computer. Both were displayed on a screen in front of the patient. The target oscillated in Simple Harmonic Motion (SHM) at a frequency of 1, 2 or 3 Hz. Changes in voltage across a potentiometer correspond to angular movement. A strain gauge measured the torque exerted when the ankle was moved passively. The voltage from this, the goniometer and the EMG signals were recorded on video tape, digitised by Softel and analysed using Excel.

Surface EMGs were recorded using Medelec contact electrodes with integral pre-amplifiers. In the walking test ankle angle was recorded using a Penny and Giles electro-goniometer and foot-switches (force sensitive resistors) under the heel and first metatarsal head of both feet were used to compute gait parameters so that muscle activation and ankle movement could be correlated with phases of the gait cycle.

Co-activation and stretch indices, resistance to passive movement and control of voluntary movement were measured in the rig. The co-activation index was expressed as: sum of EMG activity during the prime mover phase divided by the sum of EMG activity during the relaxation phase. In healthy subjects, where there was reciprocal inhibition, this index was small. Where there was co-activation it was closer to one. The stretch index was expressed as: sum of EMG activity during the stretch phase divided by the sum of EMG activity during the shortening phase. In the presence of a stretch response this ratio is greater than one. Accuracy in following the trace was measured by integrating the error between the tracking target trace and the ankle movement that actually occurred. Phase differences and peaks of movement ranges were calculated. Resistance to passive movement was measured as torque about the ankle joint.



Walking speed was measured over ten metres and at the same time Physiological cost index (PCI) was calculated to indicate the effort of walking. Walking speed, PCI and gait symmetry were measured both with and without FES. Spasticity was measured by the modified Ashworth score and by the presence and degree of clonus on a scale of 0-2.

Subjects used an FES device to correct foot-drop while walking. Stimulation was applied through surface electrodes using standard electrode positions and stimulation parameters.