Analysis used in determining a measure for spasticity in the calf muscles in stroke patients

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1 Introduction

Spasticity in the calf muscles is a common problem in stroke sufferers. It can significantly affect a patient's gait and is one of the most difficult post-stroke results which needs to be addressed to correct for dropped-foot. Its exact cause is unclear, but two factors that are functionally important are an increase in calf stretch reflex and a lack of reciprocal inhibition when the anterior tibials are activated. Therefore, to determine a measure of spasticity it is important to investigate its response to passive and to active movement. By measuring the ankle movement and EMGs from the anterior tibials and the calf muscles, indices can be calculated. These may be useful in determining a measure for spasticity. The analysis used to determine these indices are described and is to be considered in conjunction with its companion paper[1].

2 System description

By restraining a subject's lower leg and foot in a jointed rig, the ankle may be moved actively or passively in response to a cursor, the *trace* signal, moving across a PC screen in a sinusoidal manner. The ability of the subject's ankle to do this is monitored by an electrogoniometer, which measures the angle at the ankle, *gonio* signal, and surface electromyograms (EMGs) from the anterior tibials and the calf muscles. Resistance to passive movement, *torque*, is measured by a strain gauge on a lever arm at the ankle joint. Test data is collected on the text lines of a video using a Softel data logging system and from this a five second run is selected. The data is converted into a format suitable for downloading into *Microsoft Excel* and analysed using a macro written in *Quick Basic*.

3 Measures calculated to describe spasticity

Ability of the subject to control their ankle

This is measured by comparing the *gonio* signal to the *trace* signal. Differences between the two signals are measured by calculating the phase difference, the ratio of the positive (and negative) peak value of each signal and the ratio of the areas under one positive (and negative) cycle of each signal.

Co-activation between anterior tibials and the calf muscles during active movement

EMG activity is calculated from the point of maximum plantar-flexion to maximum dorsiflexion and vice-versa. An index, termed the co-activation index, is calculated as the ratio between the EMG activity when the muscle is in its relaxation phase to the EMG activity when the muscle is in its prime-mover phase. Near zero EMG activity when the muscle is not acting as the prime mover indicates reciprocal inhibition. To determine a measure showing when both muscles are on, the overlap time and the EMG activity overlap, as a percentage of the total EMG activity during the phase, is calculated.

EMG activity and resistance to passive movement

EMG activity from when the muscle is stretching to when it is shortening is calculated between plantar-flexion and dorsiflexion and vice-versa. From this an index is calculated which is the ratio of the EMG activity between the two phases. The resistance to passive movement is measured by finding the peak *torque* as the ankle goes into plantar-flexion and into dorsiflexion and by calculating the areas under the positive and negative cycles of the *torque*-time graph.

4 Software design

The *Excel*-based software calculates the indices used to describe spasticity and formats the graphical results. First, each data channel is examined for spikes which may result in erroneous threshold crossings. These are defined if the value is more than the previous input value by more than a pre-defined number and are removed by fixing the value at this previous value.

The main crux of the software depends upon accurately determining the crossing points of threshold or zero levels for the input signals. These are used to define time markings between which to calculate the peaks in the signals or areas under the graph. Fluctuations around thresholds and zero-levels result in multiple crossing points appearing at just one true one and need to be removed. This is by examining the previous five and successive five data values to any crossing point. If any cross back over the threshold, then the input value is regarded as a fluctuation and given a new value, that of the previous input value. The method has proved very reliable.

EMG activity is calculated by summing the area under the root-mean-square EMG-time graph between two defined time markings. The main problem still existing with the software is how to determine when a muscle is active and when it is inactive. A threshold needs to be defined above which a muscle is considered active. At first it was defined by examining the results from many subjects, but in later tests this threshold was shown to be unsatisfactory. For some the EMGs were so small that they lay below the threshold and for others the 'noise' during the inactive period was so great that the software calculated erroneous threshold crossings. The user is now prompted for a threshold level, manually determined from the EMG graphs. However, this means that different EMG thresholds are used, for different subjects and different tests, and that it is less user-friendly. Therefore, we are currently investigating alternative options.

5 Conclusions

An *Excel*-based analysis package has been developed to calculate the 'measures of spasticity' of the calf muscles in response to passive and active movement. It has proved very useful and the idea has been extended into investigations when the patient is walking. One remaining problem is in determining the EMG threshold and this has prompted us to consider further development of the system, both in hardware and software.

References

1 Burridge JH, Wood DE, Taylor PN, Crook SE and McLellan DL. An investigation into the relationship between types of muscle dysfunction and response to common peroneal nerve stimulation. *5th IPEMB FES Conference:* Salisbury, UK; March 1997.