RELATIONSHIP BETWEEN NEURAL-REFLEX TORQUE AND MUSCLE REFLEX RESPONSE IN PARKINSONIAN RIGIDITY

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INTRODUCTION

Parkinson’s disease (PD) is a progressive neurodegenerative disorder. Rigidity is one of the most disabling symptoms of PD and is defined as an increase in resistance to a passive movement persistent through the entire range of motion. Rigidity is quantified by measuring the imposed torque resistance about the joint being examined. Evidence has indicated that both neural component and non-neural component contribute to rigidity [1,2]. The neural component refers to increased reflex responses to passive stretch of the muscle. The non-neural component refers to altered mechanical properties of the passive tissues and muscle fibers.

System Identification and Modeling Approach (SIMA) is one technique used to differentiate between neural and non-neural components associated with increased muscle tone. SIMA technique has previously been used to quantify the two components in healthy individuals, subjects with stroke [3] or spinal cord injury [4]. In this study, SIMA was applied to quantify the neural and non-neural components in parkinsonian rigidity. Given that neural component of torque resistance is mainly attributed to muscle reflex response, we hypothesize that a strong correlation exists between the neural component and reflex response. The purpose of this study was to examine the relationship between neural component and magnitude of muscular reflex response measured by EMG, and to compare with the relationship between non-neural component and magnitude of EMG in subjects with PD. Another objective was to assess the validity of the SIMA technique in differentiating the neural and non-neural components associated with PD.

METHODS

Nine patients with idiopathic PD participated in this study. Informed consent was obtained from each subject and was approved by the Institutional Review Board of Creighton University in Omaha Nebraska. A servomotor housed in a custom-built apparatus generated passive wrist flexion and extension movements in controlled patterns. In this study, a pseudorandom binary sequence (PRBS) waveform was chosen to characterize dynamic features of the reflex components.

Subjects were tested in the Off-medication (12 hours after the anti-PD medication) and On-Medication (approximately one hour after taking medicine). Each subject was seated in an adjustable chair with the wrist of the most affected hand placed in a manipulandum connected to the motor shaft. The subject’s elbow was positioned at an angle of 120°. Each subject’s wrist was kept in a neutral position. The passive movement was applied in a PRBS waveform pattern to impose joint displacement of 5° (±2.5°) at a constant velocity of 200 °/s in the Off-medication and On-medication conditions. Each condition lasted approximately 15 seconds, and three trials were collected for each condition.

Joint position was recorded using an encoder (SC904 series, PacSci, CA, US). Joint torque was measured with a torque transducer (TRT-200, Transducer Tech, US). Surface electromyography (EMG) electrodes were placed over the belly of the wrist flexor muscles (flexor carpi radialis, flexor carpi ulnaris and flexor digitorum superficialis) and extensor muscles (extensor carpi radialis longus and brevis, extensor carpi ulnaris and extensor digitorum communis) using differential surface electrodes (Delsys Inc., MA, US). The position
signal was sampled at 100 Hz and torque was sampled at 1 kHz. EMGs were amplified and band pass filtered (10 - 450 Hz) before being sampled at 1 kHz per channel.

SIMA was applied to the joint position and torque signals to separate neural and non-neural components, using the parallel-cascade structure [Figure 1]. The non-neural component (TQ_I) is the torque calculated by using mechanical properties of the joint, and neural component (TQ_R) is the torque calculated with the combination of mechanical properties and changes in muscle activation [3-6].

![Figure 1: Parallel cascade structure of neural and non-neural pathways](image)

The net torque (TQ_N), measured experimentally, is given by

\[
TQ_N = TQ_I + TQ_R
\]

TQ_I was estimated in terms of a linear, dynamic IRF, relating position, and torque. The length of this IRF was fixed at a value less than the reflex delay to prevent torques due to neural component influencing the estimate. TQ_R was estimated as a pathway comprising a differentiator, a static non-linearity (N), and linear dynamics (Reflex IRF), using a Hammerstein identification method [5].

EMG signals were low pass filtered at 20 Hz. Magnitude of EMG activity of the stretched muscles was defined as the sum of the reflex response of stretched muscles. The duration of reflex response was selected between 50 ms and 110 ms after the onset of each movement. Reflex response was calculated as the integrated EMG over the duration of the reflex response and was normalized to background EMG prior to movement onset. Pearson’s correlation coefficient was performed to examine the relationship between EMG activity and neural component of torque resistance, and between EMG activity and non-neural component.

RESULTS AND DISCUSSION

Table 1 lists the correlation coefficients between the TQ_R and EMG activity, and between TQ_I and EMG in the OFF-MED and ON-MED states, respectively. The correlation is stronger between TQ_R and EMG activity than between the TQ_I and EMG activity.

<table>
<thead>
<tr>
<th>EMG activity</th>
<th>OFF-MED</th>
<th>ON-MED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation coefficient (r)</td>
<td>TQ_R</td>
<td>TQ_I</td>
</tr>
<tr>
<td>Neural component</td>
<td>0.614</td>
<td>0.472</td>
</tr>
<tr>
<td>Non-neural component</td>
<td>0.125</td>
<td>0.101</td>
</tr>
</tbody>
</table>

The results support our hypothesis that muscular reflex response is correlated with neural component. The correlation is stronger in the OFF-MED than in the ON-MED state. Furthermore, data obtained from the study provide useful information to validate the SIMA technique in differentiating the neural from the non-neural components associated with parkinsonian rigidity.

REFERENCES


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