CARPAL TUNNEL SYNDROME IMPAIRS FINGER RESPONSES TO UNPREDICTABLE PERTURBATION

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INTRODUCTION

Successful object manipulation requires effective integration of sensory information and motor commands. Carpal tunnel syndrome (CTS), a prevalent entrapment neuropathy, is caused by chronic compression of the median nerve in the carpal tunnel. CTS patients experience sensory deficits, such as numbness, paresthesia, and reduced sensation. However, the effects of these CTS-associated sensory deficits on finger responses are not well understood. The purpose of this study was to investigate finger muscle and force responses to unpredictable perturbations in patients with CTS. We hypothesized that CTS patients would demonstrate impaired finger responses to perturbations.

METHODS

Seven CTS patients (48±16 years) and seven asymptomatic control subjects (52±12 years) participated in this study. The experimental setup for the perturbation-induced finger response task is depicted in Fig. 1.

![Figure 1: Schematic of experimental setup: (1) transducer; (2) slide; (3) baseline weight; (4) perturbation weight; (5) electromagnet.](image)

The wrist and forearm were rested on a wedged-support with the index finger parallel to the inclination surface of the support. At the beginning of each trial, the subject pressed a plate with the index finger and maintained a 3N baseline force according to provided visual feedback. The unpredictable perturbation was implemented by releasing a 100g weight from a height of 20cm at a random instant in the 20-40s time window. The subject was instructed to stop the slide from moving as quickly as possible. The activity of the first dorsal interosseous (FDI) muscle was recorded by a surface electromyography (EMG) system and the forces from the index finger were collected by a six-component force/torque transducer. A total 15 trials were completed and 9 trials were used for analysis.

Muscle and force responses to the perturbation were quantified based on latency, duration, and intensity. For each trial, the onset of perturbation was identified as the time point when the tangential force (x-direction) exceeded 3 standard deviations (SD) of its baseline (mean of the signal 5s prior to the release of the perturbation weight). Then, the signals from individual trials were synchronized according to the onsets of perturbation and averaged for each subject. From the averaged trial, the EMG/normal force signal was used to determine the onset of muscle/force response as the time point when the EMG/normal force exceeded 3SD of its respective baseline. The muscle/force response latency was defined as the time period between the onset of perturbation and the onset of muscle/force response. The time point and magnitude of the peak EMG/normal force response were also obtained. The muscle/force response duration was the time interval between the onset of muscle/force response and the time point of peak muscle/force response. Additionally, the muscle/force response intensity was defined as the ratio of the peak EMG/normal force response magnitude to the baseline EMG/normal force. The moving duration of the
slide was also derived to determine the consequence of the finger’s responses on the object. It was quantified as the time interval between the onset of perturbation and the time instant when the plate stopped sliding (i.e. when the velocity of the center of pressure measured by the transducer was zero). Independent t-tests were performed on variables between groups. A p<0.05 was considered statistically significant.

RESULTS AND DISCUSSION

For the CTS and control groups, finger responses were characterized by activation of the FDI muscle followed by increased applied normal force (Fig. 2).

Figure 2: Muscle (top) and force (bottom) responses for representative control and CTS subjects: a-onset of perturbation; b/d-onset of muscle/force response (Control); c/e-onset of muscle/force response (CTS).

Muscle and force response latencies, durations, and intensities are presented in Table 1. In comparison to the control group, the CTS group demonstrated 22.0% prolonged muscle response latency (p<0.05) and 11.7% prolonged force response latency (p<0.05). No statistical differences were found between groups for duration or intensity of the muscle or force responses. The duration of plate sliding for the CTS group (140.6 ± 3.5 ms) was significantly longer than that of the control group (135.6 ± 3.6 ms, p<0.05).

In current study, the CTS group demonstrated prolonged response latencies to unpredictable perturbations. CTS-associated changes of the cutaneous sensory function and/or adaptations of the central nervous system may have contributed to the slower responses. In particular, decreased stimulus encoding by cutaneous mechanoreceptors or deteriorated central information processing could slow down the sensorimotor integration process, resulting in the delayed responses. Although significant differences were not found for response intensities between groups (muscle: p=0.079; force: p=0.057), the CTS group displayed trends of lower response intensities. With a larger sample size, we expect this difference will be significant. If CTS patients respond less forcefully than controls to unpredictable perturbations, then this expected result is in contrast to previous studies which have reported that CTS patients use increased grip force during static precision pinch [1]. This discrepancy may be attributable to the different strategies used to complete each task [2]. Specifically, precision pinch tasks rely predominantly on anticipatory mechanisms from previous sensorimotor memories, whereas unpredictable perturbation tasks depend more on instantaneous sensory feedback from the perturbations. Together, the delayed and decreased responses may indicate a different pattern of inefficient object manipulation by CTS patients. The deteriorated efficiency of the index finger’s responses likely contributed to the prolonged duration of plate sliding, and may help to explain why CTS patients tend to drop objects.

REFERENCES


ACKNOWLEDGEMENTS

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Table 1: Finger responses to perturbations from control and CTS group (Mean ± SD, * p<0.05)

<table>
<thead>
<tr>
<th></th>
<th>Muscle Latency (ms)</th>
<th>Muscle Duration (ms)</th>
<th>Muscle Intensity (ratio)</th>
<th>Force Latency (ms)</th>
<th>Force Duration (ms)</th>
<th>Force Intensity (ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>77.1± 9.6*</td>
<td>166.7 ± 22.4</td>
<td>9.6 ± 3.5</td>
<td>103.7± 6.7*</td>
<td>233.6 ± 31.3</td>
<td>8.0 ± 2.4</td>
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<tr>
<td>CTS</td>
<td>94.1±17.1*</td>
<td>181.3 ± 53.6</td>
<td>6.6 ± 2.1</td>
<td>115.9±12.5*</td>
<td>263.9 ± 32.5</td>
<td>5.4 ± 2.0</td>
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