New Approach to Characterize Trunk Neuromuscular Responses During Rapid Voluntary Extremity Movement

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INTRODUCTION

Assessing trunk muscle postural responses to perturbation is important for detecting neuromuscular dysfunction in patients with lumbopelvic pain. During rapid voluntary extremity movement, anticipatory activation of trunk muscles is a fundamental postural strategy for controlling center of mass and trunk stability.

Traditionally anticipatory activation is defined based on standard electromagnetic delay (EMD) of 40-60ms (time between onset of extremity muscle activation and initiation of movement or force generation). However, not everyone has an EMD in this range. Therefore use of a standard EMD (e.g., 50ms) could bias the interpretation of anticipatory activation. Details about the kinematics of the extremity may be a key factor in interpreting trunk muscle responses and expanding the characterization of trunk neuromuscular control during a self-perturbation task. For example, muscle responses have been largely characterized by latency alone; however, knowing muscle latency alone does not fully describe trunk postural control during this task.

The purposes of this study are to 1) determine test-retest reliability of extremity kinematic parameters during an arm self-perturbation task and 2) describe a method for determining and classifying trunk muscle timing (Turn On and Off) responses based on kinematics of the extremity.

METHODS

Seven subjects (4 female; age= 36±8; BMI= 24±3) performed 6 repetitions of the dominant upper extremity shoulder flexion in response to an auditory stimulus. Surface EMG activity was recorded at 2400 Hz (Band pass 10-500 Hz) from 6 trunk muscles bilaterally (IO/TrA, EO, RA, LM, LES, TES) and the anterior deltoid of the dominant arm. Dominant arm and trunk displacement were also collected simultaneously by an electromagnetic device (120Hz). EMG data was heart rate stripped, and RMS filtered (20Hz). Onset and offset times of the trunk muscle phasic responses were determined by computer algorithm. The axis of rotation and the angular velocity of the humerus (arm) with respect to the trunk were calculated for each trial. The component of the angular velocity orthogonal to the plane of movement (sagittal) was segmented by an optimal linear piecewise algorithm [1] into four phases: initial resting (Phase I), rapid increase (Phase II), relative plateau (Phase III) and rapid decrease (Phase IV) to zero velocity (arm max elevation) (see Figure 1).

![Figure 1](image-url)

**Figure 1:** Schematic represents the four kinematic phases (shaded areas) determined with the optimization algorithm (green line), the anterior deltoid timing (blue line) and the EMD (dashed to solid vertical lines) during a single trial of rapid voluntary arm flexion. The black line represents arm angular rotation intensity (--- total, — sagittal). Red line is the angular velocity (---- total, — sagittal).

Trunk muscle timing was classified according to these kinematic phases. The EMD (defined as the
time from onset of anterior deltoid EMG to initial change in sagittal angular velocity of the arm) was determined for each subject. Anticipatory activation was defined for each subject as onset of trunk muscle activity during Phase I.

Test-retest reliability of extremity kinematics and anterior deltoid onset time was calculated using ICC(2,6).

RESULTS AND DISCUSSION

Individual differences in EMD (86±28ms; range 39-110ms) were found. EMD was not correlated to maximum arm angular velocity (529±62°/s). For each phase, the mean time duration and maximum flexion of the arm were: Phase I- 293±59ms, 0°; Phase II- 458±24ms, 45±11°; Phase III- 617±34ms, 123±16°; and Phase IV- 719±23ms, 143±17°. Based on our classification, all muscles, across all subjects and trials functioned in an anticipatory manner (Phase I- initial resting).

Our data (Table 1) suggest that the EMD times typically used to determine anticipatory activation (40-60ms) may actually be an under estimation. This could result in misrepresentation of anticipatory activation as voluntary activation.

CONCLUSIONS

This approach provides a tool by which to customize analysis of trunk neuromuscular control based upon the actual kinematics of the perturbation and can advance our diagnostic analyses and interventions for patients with lumbopelvic pain.

REFERENCES


ACKNOWLEDGEMENTS

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Table 1: Test-Retest Reliability of Extremity Kinematics and Deltoid Onset

<table>
<thead>
<tr>
<th></th>
<th>Test</th>
<th>Retest</th>
<th>SEM</th>
<th>95% CI</th>
<th>ICC(2,6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset of Deltoid (ms)</td>
<td>208 ±41</td>
<td>223 ±38</td>
<td>31</td>
<td>86.5</td>
<td>0.37</td>
</tr>
<tr>
<td>Onset of arm movement (ms)</td>
<td>293 ±59</td>
<td>307±50</td>
<td>23</td>
<td>63.5</td>
<td>0.82</td>
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<tr>
<td>Max Velocity (degree/s) (max1)</td>
<td>529 ±62</td>
<td>523 ±57</td>
<td>20</td>
<td>54.9</td>
<td>0.89</td>
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<tr>
<td>Max Velocity (degree/s) (max2)</td>
<td>485 ±109</td>
<td>452± 99</td>
<td>35</td>
<td>96.6</td>
<td>0.89</td>
</tr>
<tr>
<td>Max Displacement of arm (degree)</td>
<td>143± 17</td>
<td>133 ±14</td>
<td>6</td>
<td>16.9</td>
<td>0.85</td>
</tr>
<tr>
<td>Electromechanical Delay (ms)</td>
<td>86± 28</td>
<td>84± 25</td>
<td>8</td>
<td>21.1</td>
<td>0.92</td>
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</tbody>
</table>