Relation between the EMG recordings from prime movers of the arm and the Drawing Test scores in post stroke hemiplegics

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Abstract
The drawing test (DT) is a quantitative measure of the ability to voluntary move the hand. DT requires that subjects move a cordless mouse in radial direction in front of the acromion (point-to-point movements, 20 cm distance) in the horizontal plane. We investigated the relation between the DT scores (kinematic metrics) and electrical activity (EMG) recorded from the prime movers of the shoulder and elbow joints with surface electrodes in post-stroke hemiplegic patients with various levels of spasticity. The recordings were synchronous with the DT. The analysis of the EMG patterns confirmed that simple movements in post-stroke hemiplegic subjects are mostly compromised by spasticity, and that they relate to the DT scores. The EMG recordings in post-stroke hemiplegic patients with low DT score showed much higher level of co-contraction, and wider variation in the time synchrony of the EMG timing compared with the less spastic patients with higher DT score.

1 Introduction
Hemiplegic subjects often have long-lasting motor limitations preventing them to perform typical daily activities. We introduced the Drawing Test (DT) as a measure of coordination of the elbow and shoulder joints during performance of functional tasks. We used the DT in clinical trials in tetraplegic and hemiplegic patients [1]. The results showed that the DT score and motor coordination were correlated [2]. The initial DT inherently comprised a cognitive component; thereby, we reduced the DT to radial point-to-point movements in front of the left or right acromion. The test was performed while the patient was sitting, and moved the hand on the digitizing tablet positioned within the workspace at the desk. The score of this simplified DT relates only to the kinematics of movements. Here, we present the muscle activation patterns (EMG) of the prime movers of elbow and shoulder joints together with the DT scores, and the Ashworth Scale (AS) used as a clinical measure of spasticity.

2 Methods
Subjects. Eight volunteers participated in the experiments, Table.1. Each subject had sustained a hemispheric stroke at least six months prior to the study. The exclusion criteria were the following: subluxation, shoulder pain, cognitive dysfunction, neglect and apraxia, and AS=4. The local ethics committee approved the experiments following the Helsinki Declaration.

<table>
<thead>
<tr>
<th>Pt. #</th>
<th>Age (years)</th>
<th>Diagnosis</th>
<th>AS score</th>
<th>Par. side</th>
</tr>
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<tr>
<td>1</td>
<td>46</td>
<td>Hem. L. Sin., Infar.</td>
<td>3</td>
<td>ND</td>
</tr>
<tr>
<td>2</td>
<td>55</td>
<td>Hem. L. Dext</td>
<td>2</td>
<td>D</td>
</tr>
<tr>
<td>3</td>
<td>63</td>
<td>Hem. L. Sin., Haemmm</td>
<td>3</td>
<td>ND</td>
</tr>
<tr>
<td>4</td>
<td>21</td>
<td>Hem. L. Dext</td>
<td>1</td>
<td>ND</td>
</tr>
<tr>
<td>5</td>
<td>49</td>
<td>Hem. L. Sin.</td>
<td>1</td>
<td>D</td>
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<td>6</td>
<td>41</td>
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<tr>
<td>7</td>
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<td>Hem. L. Sin.</td>
<td>1</td>
<td>ND</td>
</tr>
<tr>
<td>8</td>
<td>49</td>
<td>Hem. L. Sin., Infar.</td>
<td>3</td>
<td>ND</td>
</tr>
</tbody>
</table>

Table 1: Demographics for eight chronic hemiplegic patients. All patients are right handed. Patients #2, #4 and #8 are female. AS – Ashworth Scale score (0-4). D – dominant. ND – non-dominant.
Data acquisition. Four corners of a square with sides of 20 cm were marked at the digitizing table, and labeled with A, B, C, and D, (Figure 1a), starting from the left corner proximal to the left acromion in clockwise direction. Subjects were instructed to move the mouse with their paretic arm from A to B (left side hemiplegia), and D to C (right side hemiplegia). Before the recording sessions, subjects practiced the drawing. If a subject was not able to hold the magnetic mouse, then the mouse was attached to the hand by a Velcro™ tape on a light soft cuff that was wrapped around the fingers. In this case the hand was positioned in a pronated position to allow the mouse to slide without a tendency to tilt.

The movements A to B, or D to C were repeated five times. All participants were instructed to relax their arm muscles as much as possible before and after each movement.

The trajectories were recorded on a Drawing Board III™ (GTCO Calcomp, Inc., Arizona, U.S.A.) with a precision of \( \pm 0.25 \) mm and sampled at 100 Hz.

The position data were used to calculate the maximum radial error \( Y_m \), and the standard deviation \( e(x) \) as shown in Figure 1.b. The values \( Y_m \) and \( e(x) \) were used to determined the DT score by using the regression formula determined in our earlier study [3]:

\[
DT = 0.0043Y_m + 1.19 \log(e(x))
\]

An expert physiotherapist used the five-grade Ashworth Scale (AS) to assess the spasticity of the elbow joint.

Synchronously to the DT movement we recorded the surface EMG from the paretic prime movers of the elbow. We placed disposable Ag/AgCl electrodes for EMG recordings (Medicotest A/S) within an inter-electrode distance of 2 cm over the elbow flexor (\textit{m. Biceps Brachii}, (BB)), the elbow extensor (lateral head of \textit{m. Triceps Brachii} (TB) and shoulder flexors and extensors (\textit{m. Teres Minor} and \textit{m. Latissimus Dorsi}, respectively). Surface EMG was amplified 20000 and 100000 times, sampled at 1000 Hz, and band-pass filtered between 15 Hz and 300 Hz by a 6th order elliptic filter by a custom developed Labview™ routine.

### 3 Results

All trials were first visually inspected, and the erratic ones disregarded.

Figure 2 illustrates EMG patterns and kinematics for two hemiplegic patients with assigned AS scores: a) PT4 (AS=1); and b) PT1 (AS=3).

The patient with lower spasticity (AS=1) had activation of TB muscle prior to the onset of the elbow extension (left two middle panels) (Fig. 2a). There was a co-activation of BB muscle (left two top panels). After the subject finished the movement the TB muscle was silent. Two left bottom panels show kinematics: the movement in the tangential (x) direction was minimal, and the movement in the radial (y) direction was successful. The maximum hand velocity in the direction of the y axis \( v_y(t) \) was very low (approximately 5 cm/s), yet it followed bell-shaped velocity profile. The velocity of the hand in the direction of the x axis \( v_x(t) \) varied slightly around 0.
The recordings from the patient with higher spasticity (AS=3) show that amplitudes of EMG activities in BB and TB muscles (right top and third from the top panels of Figure 2b) do not contain clear modulation along the movement; yet, the spectrogram revealed a marked increase in TB muscle activity at frequencies up to about 200 Hz at the onset of movement (right fourth from the top panel). BB muscle firing showed an increase in activity at frequencies higher than 200 Hz at prior to the movement (right second from the top panel). The higher-frequency content is likely related to the increase of the firing rate. The high level of co-activation indicates increased (mechanical) co-contraction. The second graph from the bottom, right panel shows that the end point of the hand path deviated greatly from the desired target. The hand moved for about 5 cm in the x and y directions. The movement was also characterized by a highly variable and far from bell-shaped profile in both the x and y directions (two bottom panels).

4 Discussion and Conclusions

Table 2 shows the summary from all eight patients. According to their AS scores (first column), we grouped 8 patients into three groups (second column). The third column presents main ± S.D. DT score calculated for the assigned group. It was obtained by using regression formula. The recorded EMG data showed great variability among the subjects; yet, acceptable reproducibility from trial to trial. EMG recordings were analyzed to confirm that the inability to generate smooth hand movements between the initial and target points was mainly due to spasticity. The increased muscle tonus, and higher level of co-contractions was the primary cause of poor co-ordination. Main characteristics of EMG recordings from muscles for each group were summarized in the last column of Table 2.

References


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