Comparison of Kinesia™ to the Unified Parkinson’s Disease Rating Scale: Tremor and Bradykinesia Results

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Introduction

The current standard for evaluating motor symptoms associated with Parkinson’s disease is the Unified Parkinson’s Disease Rating Scale (UPDRS), a qualitative assessment completed during an office visit. Motor symptoms are rated on a scale from 0 – 4 corresponding to normal, slight, mild, moderate, and severe. However, interpretation of a single examination is limited, particularly in patients with motor fluctuations. Periodic, objective monitoring of symptoms at home may therefore aid in evaluating the efficacy of treatment protocols and improve overall patient management. The aim of this study is to correlate objective measurements (obtained by a wireless movement disorder monitor system, Kinesia™, CleveMed) of tremor and bradykinesia in patients with Parkinson’s disease (PD) with subjective assessments by experienced clinicians.

Methods

Kinesia™ is a user-worn, compact wireless system that uses three orthogonal accelerometers and three orthogonal gyroscopes to monitor three-dimensional motion. Tremor and upper extremity bradykinesia subsets of UPDRS motor exam were conducted on sixty patients with Kinesia worn on the hand. UPDRS scores for tremor and bradykinesia were assigned by two movement disorder specialists. The collected data were processed and used to design, train, and test an algorithm that predicted clinician scores for each task.

Results: Tremor

In order to compare the Kinesia rating to the clinical UPDRS scores, the following linear model was used to regress the clinician ratings on the peak powers:

\[ R = b_0 + b_1 \cdot P_x + b_2 \cdot P_y + b_3 \cdot P_z \]  

(Eq. 1)

where R is the clinician’s rating and \( P_x, P_y, P_z \) are all 3-D vectors. \( P_x, P_y, \) and \( P_z \) are the logarithms of the peak powers for the three accelerometers and three gyroscopes, respectively, and \( b_0, b_1, b_2, \) and \( b_3 \) are the regression coefficients.

\[ R = a_B \cdot P_B + a_P \cdot P_P + a_P \cdot P_P + a_B \cdot P_B + a_B \cdot P_B + a_B \cdot P_B \]  

(Regression 1)

Figure 3. The six raw linear acceleration and angular velocity channels and their corresponding power spectra are shown for a patient with an average rest tremor score of 1.25, slight (A) and a patient with a rest tremor score of 3.0, moderate (B). The increase in tremor severity is quite noticeable the peaks in the power spectra.

In order to test how well our model generalizes, a ‘one left out’ analysis was performed. For this analysis, the regression (Eq. 1) was performed using all but one data point. The regression model was then used to predict the single data point that was left out. The analysis was repeated leaving each data point out once and the average root mean-square (RMS) errors between the predicted and actual scores were calculated. The predicted scores correlated quite well with the actual scores (Table 1).

Table 1. Tremor Regression Statistics

<table>
<thead>
<tr>
<th></th>
<th>Regression ( r^2 )</th>
<th>Generalization ( r^2 )</th>
<th>RMS Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest Tremor</td>
<td>0.89</td>
<td>0.85</td>
<td>0.32</td>
</tr>
<tr>
<td>Postural Tremor</td>
<td>0.90</td>
<td>0.88</td>
<td>0.35</td>
</tr>
<tr>
<td>Kinetic Tremor</td>
<td>0.54</td>
<td>0.42</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Figure 4. The logarithm of the peak in power spectra is plotted versus the average clinician score for the three tasks. Average clinician score was rounded to the nearest whole number. The tips and bottoms of each ‘box’ are the 25th and 75th percentiles of the samples, respectively. A linear relationship exists between the log of the peak power and UPDRS clinician score.

In order to compare the Kinesia rating to the clinical UPDRS scores, the following linear model was used to regress the clinician ratings on the peak powers:

\[ R = a_B \cdot P_B + a_P \cdot P_P + a_P \cdot P_P + a_B \cdot P_B + a_B \cdot P_B + a_B \cdot P_B \]  

(Regression 1)

Figure 5. Three channels of angular velocity during the hand grasp task are shown for a patient with scores bradykinesia (top, UPDRS 3.0) and one left out (bottom, UPDRS 0.5). The hand is not moving during the time period labeled as ‘L’. In the bottom plot, the signal has a consistent amplitude and frequency and appears relatively constant. Conversely, based on the plot, it is clear that the patient with severe bradykinesia has a much lower and inconsistent amplitude and frequency and often hesitates.

Figure 6. Unlike with tremor, the logarithm of the peak power during the three bradykinesia tasks is not well correlated with the clinician UPDRS score.

Conclusions

The Kinesia™ system is a portable, movement disorder monitor that objectively quantifies the kinematics of movement disorder motor symptoms. This allows for continuous or periodic home monitoring of the severity of motor symptoms associated with Parkinson’s disease and other movement disorders. In addition, Kinesia can be used as an assessment of existing and novel therapeutic interventions.

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