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.

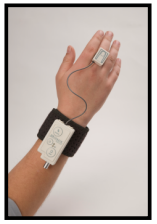


Figure 1. Kinesia™ consists of a finger worn sensor unit that contains accelerometers and gyroscopes, and a wrist worn command module that wirelessly transmits data to a computer.

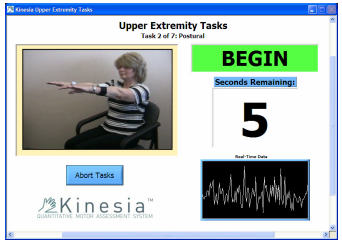


Figure 2. The Kinesia software uses clinical videos to automatically guide patients through motor tasks while motion data are being recorded.

Tremor:
- Rest
- Posture
- Action

Bradykinesia:
- Finger taps
- Hand grasps
- Rapid alternating movements

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:

$$R = b_0 + \vec{B}_a \cdot \vec{P}_a + \vec{B}_g \cdot \vec{P}_g \qquad \text{(Eq. 1)}$$

where R is the clinician's rating and $\vec{B}_a$, $\vec{B}_g$, $\vec{P}_a$, and $\vec{P}_g$ are all 3-D vectors. $\vec{P}_a$ and $\vec{P}_g$ are the logarithms of the peak powers for the three accelerometers and three gyroscopes, respectively, and $\vec{B}_a$, $\vec{B}_g$, and b_0 are the regression coefficients.

Results: Tremor

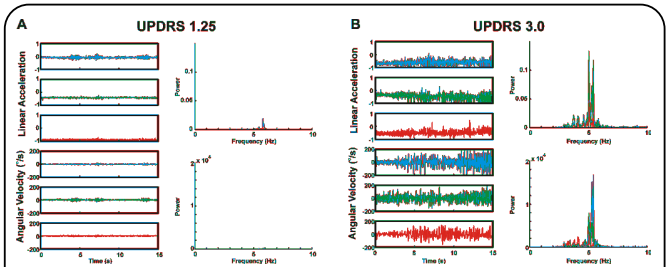


Figure 3. The six raw linear acceleration and angular velocity channels and their corresponding power spectra are shown for a patient with an average rest tremor score of 1.25, slight (**A**) and a patient with a rest tremor score of 3.0, moderate (**B**). The increase in tremor severity is quite noticeable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

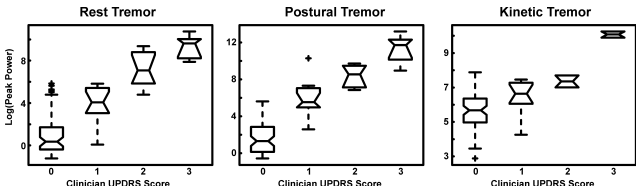
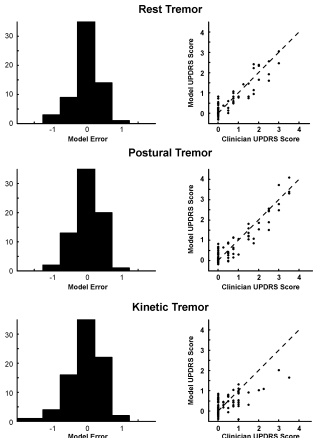


Figure 4. The logarithm of the peak in power spectra is plotted versus the average clinician score for the three tasks. Average clinician score was rounded to the nearest whole number. The tops and bottoms of each "box" are the 25th and 75th percentiles of the samples, respectively. A linear relationship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



In order to 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 clinician UPDRS scores and the predicted scores were calculated.

The predicted scores correlated quite well with the actual scores (Table 1).

Figure 5. For each of the three tremor tasks, the score predicted from the "one left out" model is plotted versus the average clinician UPDRS score (right). Histograms (left) plot the RMS error between the predicted and actual scores.

Table 1. Tremor Regression Statistics

	Regression r^2	Generalization r^2	RMS Error
Rest Tremor	0.89	0.85	0.32
Postural Tremor	0.90	0.88	0.35
Kinetic Tremor	0.54	0.42	0.51

Results: Bradykinesia

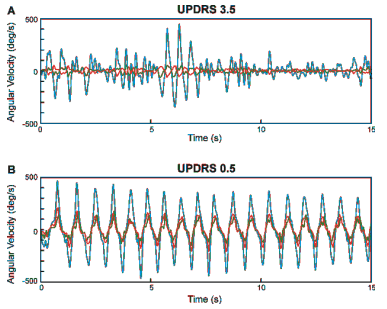


Figure 6. Three channels of angular velocity during the hand grasp task are shown for a patient with severe bradykinesia (top, UPDRS 3.5) and mild bradykinesia (bottom, UPDRS 0.5). In the bottom plot, the signals have a consistent amplitude and frequency and appear sinusoidal. Conversely, based on the plot, it is clear that the patient with severe bradykinesia has a much lower and inconsistent amplitude and frequency and often hesitates.

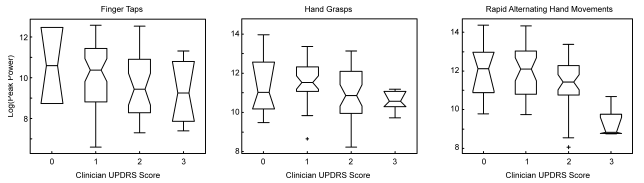


Figure 7. Unlike with tremor, the logarithm of the peak power during the three bradykinesia tasks is not well correlated with the clinician UPDRS score.

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.

Acknowledgements

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