Automated Parkinson's Disease Motor Assessment for Clinical and Ambulatory Monitoring

Dustin A. Heldman, Ph.D.[1], Alberto J. Espay, M.D.[2], Peter LeWitt, M.D.[3], Joseph P. Giuffrida, Ph.D.[1]

[1]Cleveland Medical Devices, Inc., Cleveland, OH, [2]Department of Neurology, Neuroscience Institute : Gardner Family Center for Parkinson's Disease & Movement Disorders, University of Cincinnati, Cincinnati, OH, [3]Henry Ford Health System, Detroit, MI

Introduction

The current standard for evaluating motor impairment associated with Parkinson's disease (PD) is the Unified Parkinson's Disease Rating Scale (UPDRS), a qualitative assessment completed during an office visit. However, interpretation of a single examination is limited, particularly in patients with motor fluctuations. Therefore, periodic, objective symptom monitoring may aid in evaluating the efficacy of treatment protocols and improve overall patient management.

Kinesia System

Kinesia™ (CleveMed) is a user-worn, compact wireless system that uses accelerometers and gyroscopes to monitor three-dimensional motion (Figure 1). The software includes an automated motor assessment, which guides patients through several motor tasks that are part of the UPDRS motor assessment (Figures 2 and 3). In a pilot study involving 60 PD subjects, algorithms were developed for objectively rating motor symptoms. In order to expand upon and further validate the scoring algorithms, a multi-center clinical study involving 150 subjects at three clinical sites was implemented.
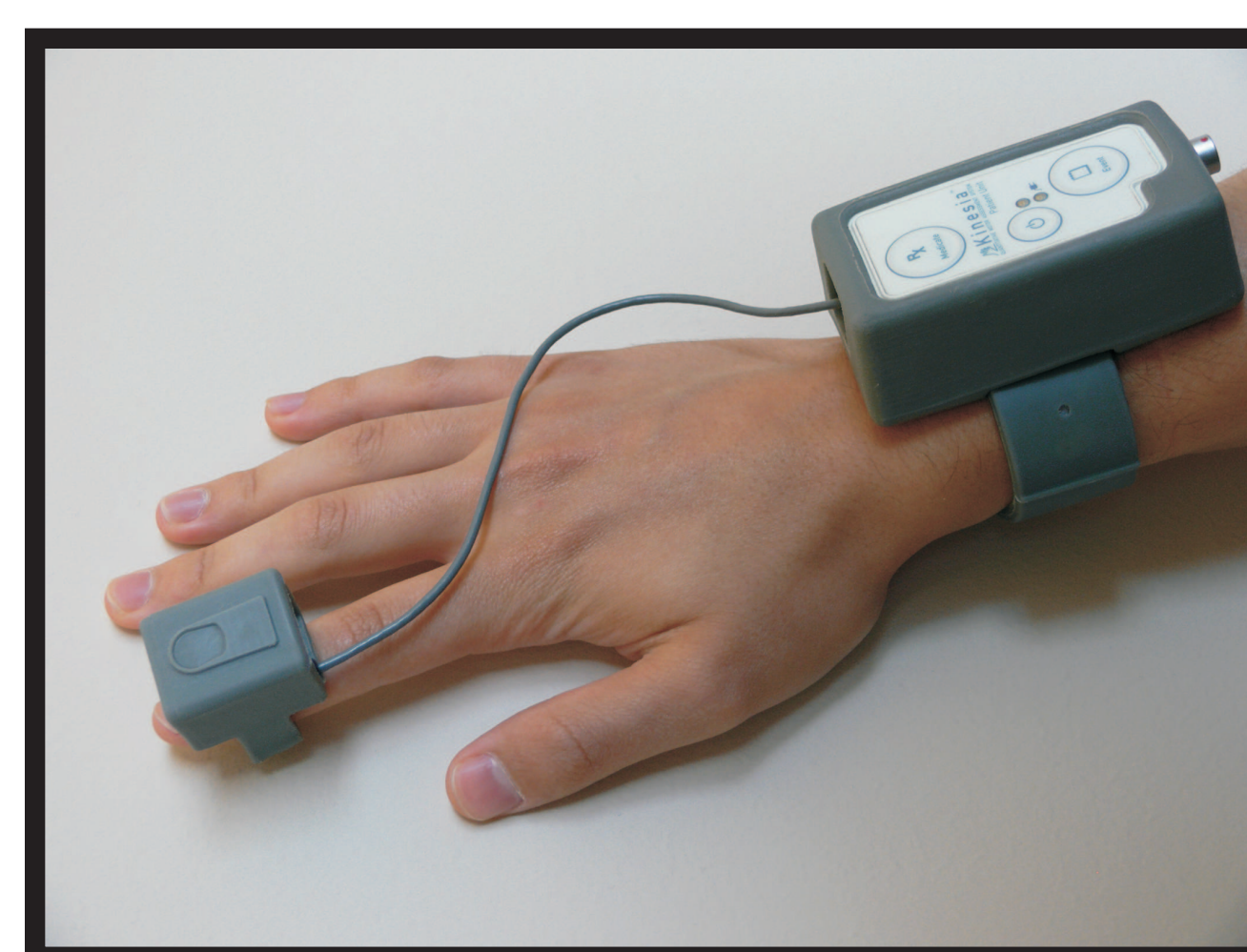
Figure 1. Kinesia™ consists of a finger worn sensor unit that contains accelerometers and gyroscopes, and a wrist worn command module that wirelessly transmits data to a computer.
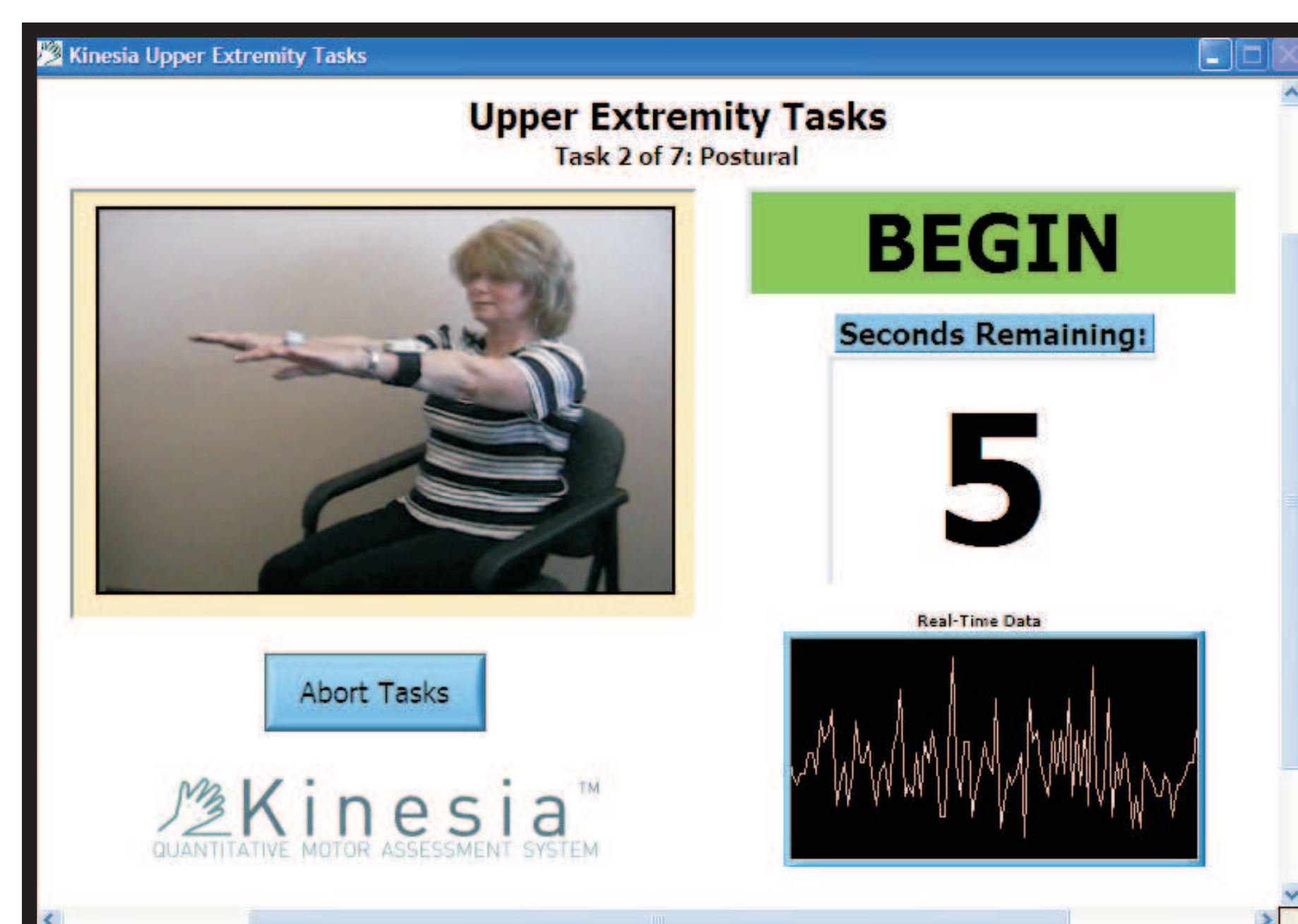
Figure 2. The Kinesia software uses clinical videos to automatically guide patients through motor tasks while motion data are being recorded.

Methods

Subjects wore the Kinesia system on the affected hand and underwent automated motor assessment (Figure 2) for several tasks (Figure 3). Subjects were videotaped for subsequent UPDRS scoring by movement disorder neurologists at three clinical test sites. Quantitative variables were extracted from the recorded motion data and correlated with clinical scores to develop a linear model for rating motor symptoms.

Rest Tremor   Postural Tremor   Kinetic Tremor

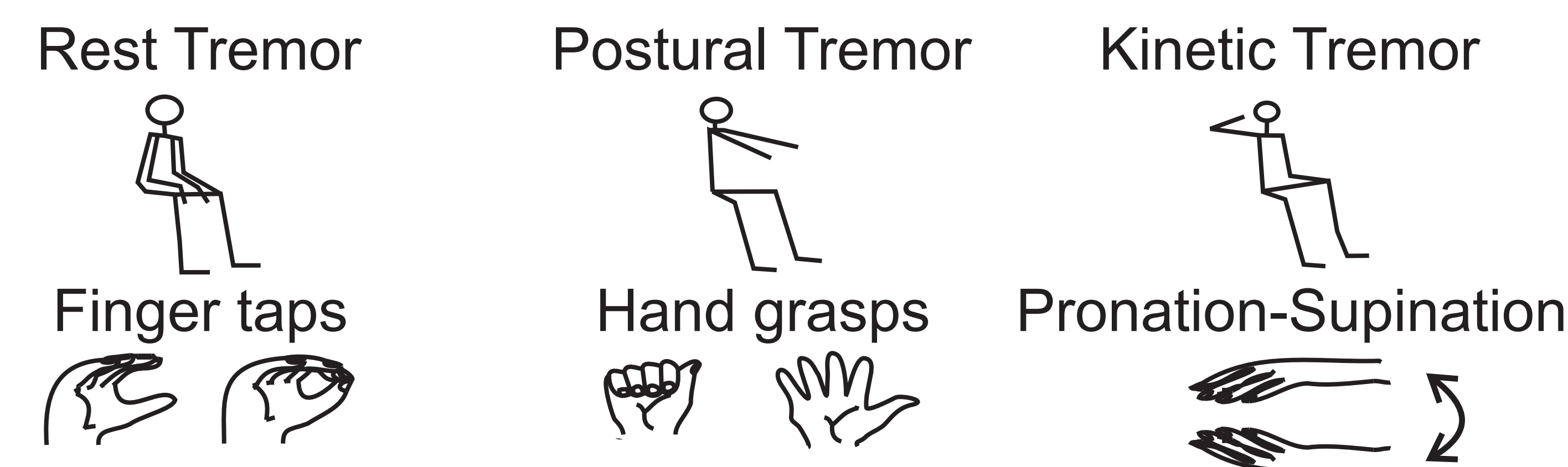Finger taps   Hand grasps   Pronation-Supination

Figure 3. The Kinesia software includes several tasks for evaluating tremor and bradykinesia.

Following the "In Clinic" study, an "At Home" examination was performed. Two subjects, both on dopaminergic drug therapy, were sent home with the Kinesia system including the patient-worn hardware and a laptop PC. Each subject took his/her medication four times per day. In addition, each subject was instructed to perform the Kinesia Automated Motor Assessment five times per day, as prescribed by their physician. The daily progression was repeated for five consecutive days.

Clinical Results

In order to test how well our model generalizes, a "one left out" analysis was performed. For this analysis, a linear regression model was developed 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. Results for tremor are shown in Figure 4.

A: $r^2 = 0.85$, RMSE = 0.32
B: $r^2 = 0.88$, RMSE = 0.35
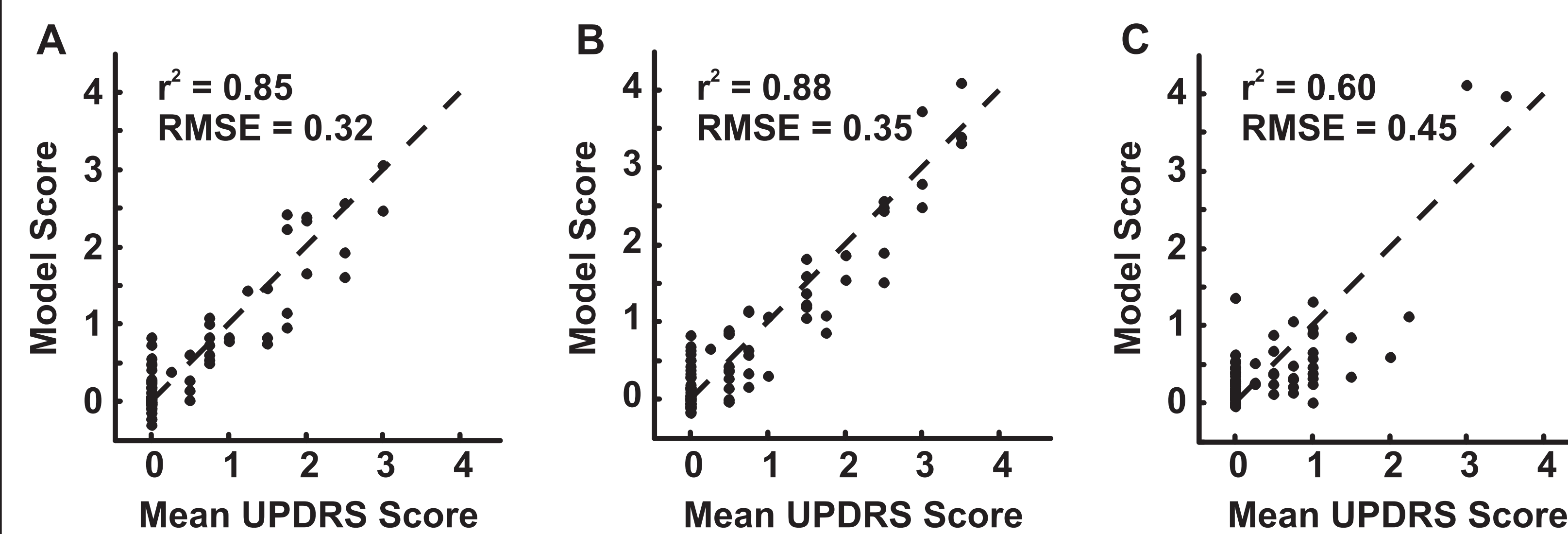C: $r^2 = 0.60$, RMSE = 0.45

Figure 4. The regression model outputs using the "one left out" technique produced low errors and good correlations to clinician scores when presented with new subject data. For rest (A), postural (B), and kinetic (C) tremor, the regression model UPDRS score is plotted versus the mean clinician UPDRS score. The dotted lines correspond to a perfect fit. Coefficient of determination (r^2) and root-mean-square errors (RMSE) are shown for each task.

Home Results

Subject 1   Subject 2

Day 1, Day 2, Day 3, Day 4, Day 5

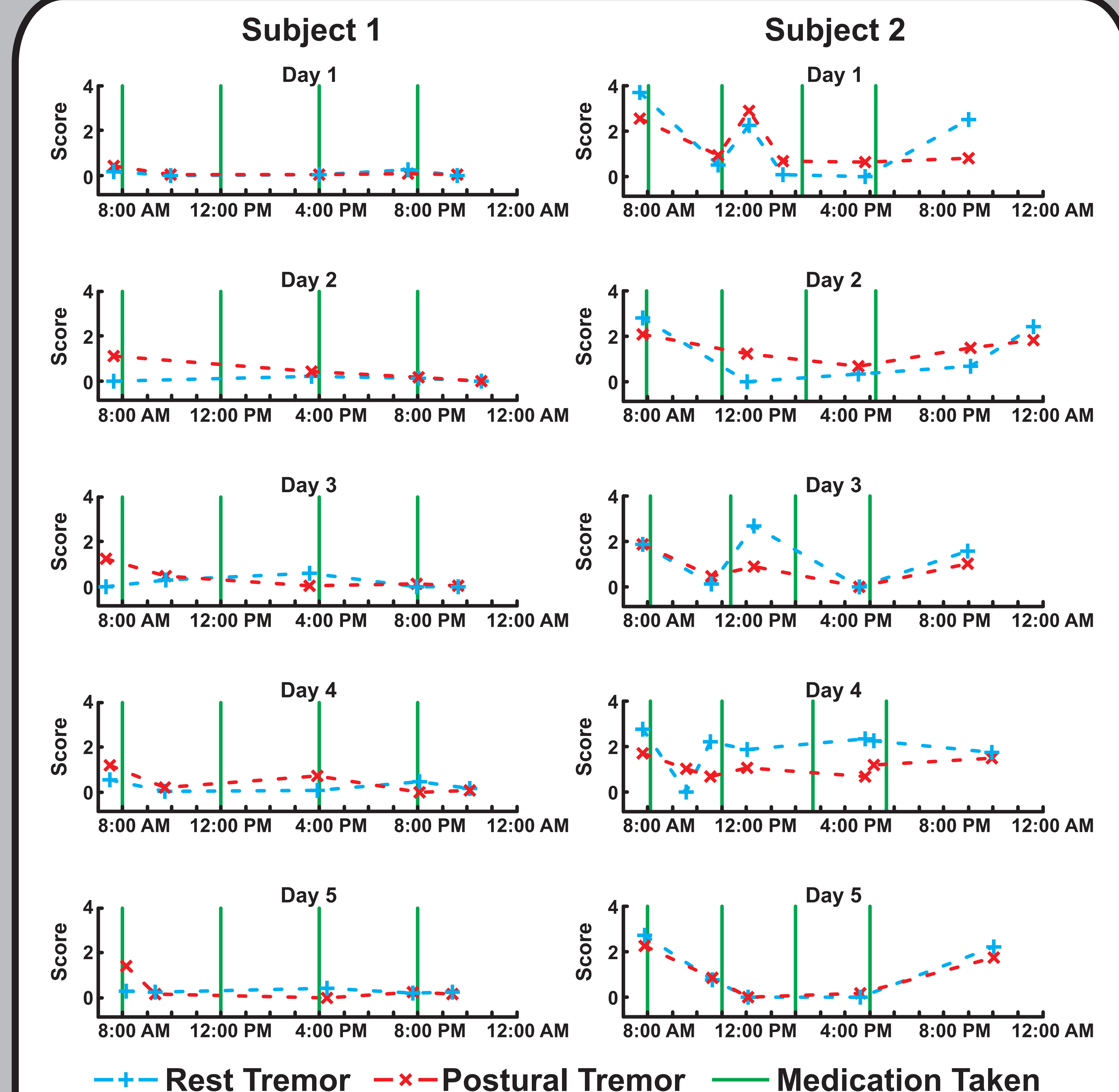Rest Tremor   Postural Tremor   Medication Taken

Figure 5. Two subjects performed the automated motor assessment four to six times per day for five consecutive days. Scores given by the Kinesia system are marked each time the assessment was performed. Rest and postural tremor scores are shown in blue and red, respectively. The vertical green lines indication when medication was taken. Subject 1's tremor is very well controlled throughout the day, while Subject 2 experiences large fluctuations.

Conclusions

The Kinesia motor assessment provides objective PD symptom scoring both in the clinic and at home. The home assessment allows for more continuous monitoring, which enables the capture of motor fluctuations that can occur throughout the day in response to medication. This increased temporal resolution may lead to the development of novel treatment options and help clinicians better prescribe and adjust therapies.