Continuous Home Monitoring of Essential Tremor Using Motion Sensors

Dustin Heldman[1], Christopher Pulliam[1], Sheila Eichenseer[2], Christopher Goetz[2], Olga Waln[3], Christine Hunter[3], Joseph Jankovic[3], David Vaillancourt[4], and Joseph Giuffrida[1]

[1]Great Lakes Neurotechnologies, Cleveland, OH; [2]Rush University Medical Center, Chicago, IL; [3]Baylor College of Medicine, Houston, TX; [4]University of Florida, Gainesville, FL

Introduction

Essential tremor (ET) is typically measured in the clinic with a tremor rating scale. While these ratings are used to adjust medication regimen, they require the presence of a clinician for scoring and are thus not appropriate for measuring severity throughout the day. Previous studies have demonstrated the utility of motion sensors in evaluating ET under known conditions. The objective of this study was to evaluate the ability of motion sensors to classify and quantify tremor in patients with ET during unconstrained activities at home.

Methods

- 20 patients with ET wore a wireless motion sensor (Fig 1) containing a triaxial accelerometer and gyroscope on the finger for up to 10 hours on each of two separate days as they went about their normal routines.
- At one-hour intervals, the subjects also performed previously validated motion sensor-based standardized tremor assessments consisting of pre-defined tasks to evaluate rest, postural, and kinetic tremor (Fig 2).
- Recorded kinematics were processed into 0-4 severity ratings using previously validated algorithms (Heldman et al., 2011) for standardized assessments and a new multiple regression model for continuous tremor ratings.
- The day-to-day test-retest reliability of both rating types were assessed by calculating the intraclass correlation coefficients (ICCs).
- Ratings from the hourly standardized assessments were used to periodically evaluate the accuracy of continuous ratings during unconstrained activities.

Figure 1. The Kinesia HomeView system includes a wireless finger-worn sensor unit (A) and a touch-screen tablet PC with a wireless inductive charging pad for the sensor unit (B).

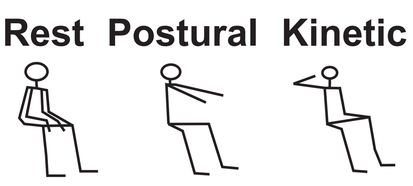


Figure 2. The Kinesia HomeView system provides instructional videos on the tablet PC to guide subjects through the standardized tremor assessment tasks.

Table 1. Subject Demographics

Age	Gender	Disease Duration	On Medication
45-85 years	11 male, 9 female	2-60 years	15 yes, 5 no

Continuous Tremor Severity Ratings

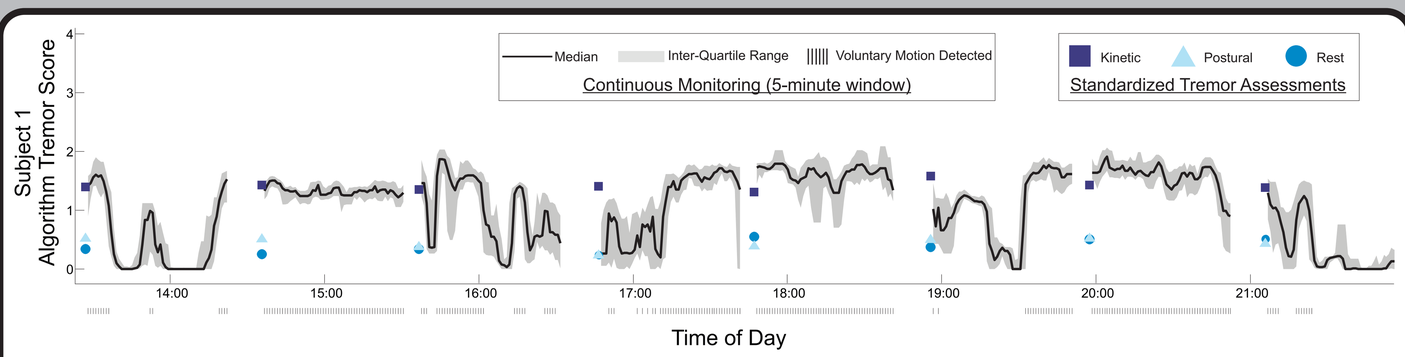


Figure 3 (top). Continuous tremor scoring during the day for one subject. The thin black line represents the median score in a sliding 5-minute window. The shaded gray region represents the interquartile distance in each of these windows. Markers show the hourly standardized tremor assessment scores for kinetic, postural, and rest tremor. The vertical tick marks at the bottom of the graph indicate when voluntary motion was detected.

Figure 4 (right - upper). Percentage of time at different tremor severities when voluntary motion was detected for two subjects.

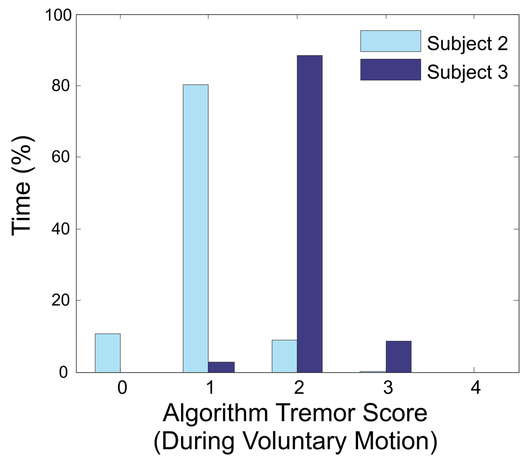


Table 2 (right - lower). Test-retest reliability from day 1 to day 2, as quantified by the intraclass correlation coefficients, for the amount of time at teach tremor severity.

	0	1	2	3
ICC	0.78	0.90	0.88	0.67

Time

- Percentage of time for which the vector norm of the angular velocities exceeded 20 º/s
- Standard deviation of angular velocity along the axis with the largest value
- Standard deviation of the first derivative of the angular velocity along the axis with the largest value
- Average interquartile ranges of the first derivatives of the accelerations
- Number of zero crossings in the acceleration and angular velocity along the axes with the largest respective values
- Number of peaks in the acceleration along the axis with the largest value

Frequency

- Ratio of power in the tremor band to that in the voluntary movement band
- Ratio of the peak in the tremor band to that in the voluntary movement band
- Logarithm of the peak in the tremor band of the power spectrum for of the accelerations and angular velocities

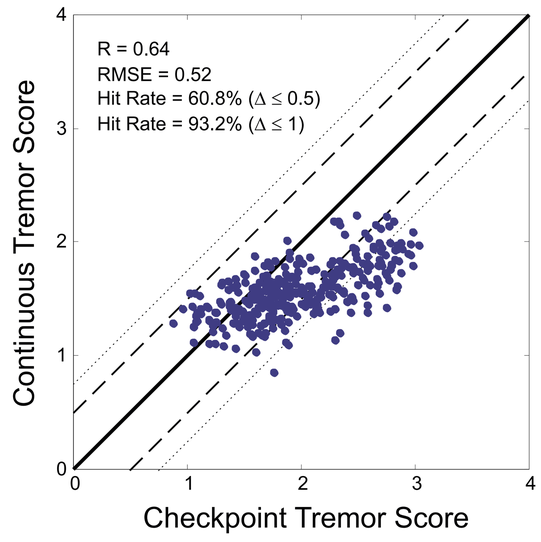
Table 3. Descriptions of time- and frequency-domain kinematic features used in the multiple linear regression algorithm to predict tremor severity scores every 12 seconds during unconstrained activities

Standardized Tremor Severity Ratings

	Intraday Mean	Intraday Range	ICC
Rest Tremor	0.85 ± 0.52	0.94 ± 0.41	0.77
Postural Tremor	0.96 ± 0.59	0.80 ± 0.50	0.91
Kinetic Tremor	1.97 ± 0.47	0.50 ± 0.20	0.95

Table 4 (above). Summary of tremor statistics for all subjects (mean ± standard deviation). Kinetic tremor was, on average, more severe than rest or postural tremor. Severity did not exhibit significant fluctuations throughout the day (rmANOVA, $p > 0.13$). Day-to-day test-retest reliability is given as the ICC for each tremor type.

Figure 5 (right). The scores output by the model for kinetic tremor during the standardized assessments are compared to the mean score output by the continuous tremor model during any periods of voluntary motion in the five minutes immediately following each checkpoint.



Conclusions

- Tremor can be rated continuously during routine activities of daily living, which may help clinicians optimize therapy, expand care to underserved populations, and aid the evaluation of new therapies.
- Subjects with ET were able to don and wear the ring-like motion sensors throughout the day as they went about their regular routines.
- Standardized tremor assessments performed once an hour throughout the day show little temporal variability in tremor severity.
- Both standardized and continuous tremor assessments exhibited high test-retest reliability.

Acknowledgment - This work was supported by NIH/NIA 2R44AG034708-02A1. The content is the sole responsibility of the authors and does not necessarily reflect the views of the National Institutes of Health or the National Institute on Aging.

A PDF of this poster and information on other Great Lakes NeuroTechnologies presentations and publications can be accessed by scanning the QR code.