Continuous Home Monitoring of Essential Tremor Using Motion Sensors

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Introduction

Essential tremor(ET) is typically measured in the clinic with one of several tremor rating scales. 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 evaluation of ET in a clinic setting 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

- Twenty patients with ET wore a wireless motion sensor containing a triaxial accelerometer and gyroscope on the finger for up to 10 hours on two consecutive days.

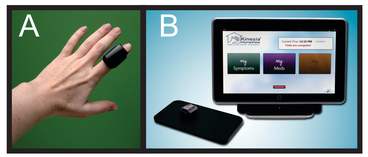


Figure 1. The Kinesia HomeView system includes a wireless finger-worn sensor unit (A) and a touch-screen tablet PC with a wireless inductive charging pad for the sensor unit (B).

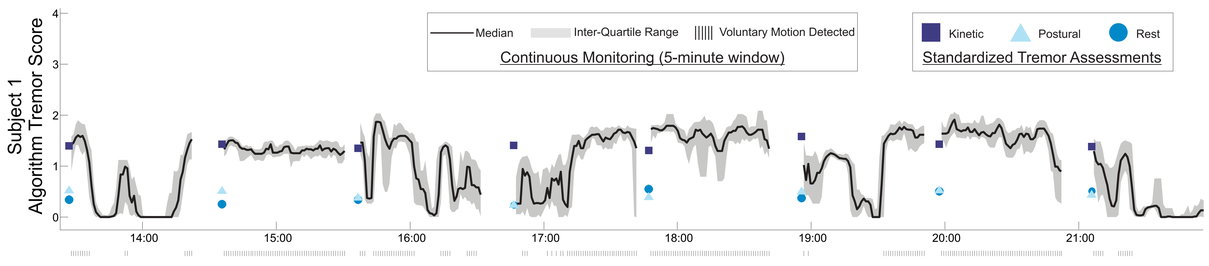
Figure 2. The Kinesia HomeView system provides instructional videos on the tablet PC to guide subjects through the standardized tremor assessment tasks.

- 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.
- Recorded kinematics were processed into 0-4 severity ratings using previously validated algorithms showing high correlations to clinical ratings. Ratings from the hourly standardized assessments were used to periodically evaluate the accuracy of continuous ratings during unconstrained activities.

Table 1. Subject Demographics

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

Continuous Tremor Severity Rating



Time	• Percentage of time for which the vector norm of the angular velocities exceeded 20 °/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 2. 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.

Figure 3 (top left). 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.

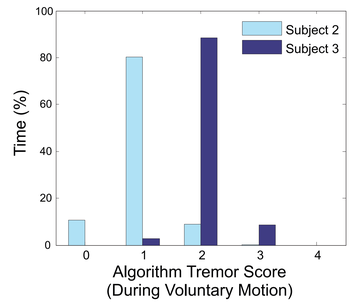


Figure 4 (top right). Percentage of time at different tremor severities when voluntary motion was detected for two subjects.

Table 3 (bottom right). Impact of sensor duty cycle on accuracy of tremor waveforms. Median value followed by 1st and 3rd quartiles.

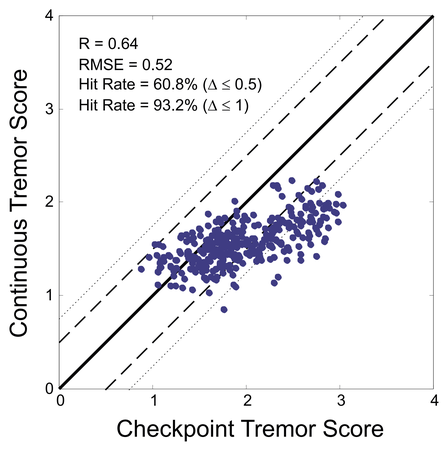
	R	RMSE
1/2 Duty Cycle	0.96 (0.92-0.98)	0.11 (0.09-0.14)
1/3 Duty Cycle	0.92 (0.86-0.96)	0.16 (0.12-0.19)
1/4 Duty Cycle	0.89 (0.80-0.94)	0.19 (0.15-0.23)

Standardized Task Tremor Severity Ratings

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

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.

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 model during any periods of voluntary motion in the five minutes immediately following each checkpoint.



Conclusions

- Tremor can be rated continuously during routine, unconstrained activities of daily living in the home
- Subjects with ET were able to don and wear the ring-like motion sensors without significant interference with regular activities
- Standardized tremor assessments performed once an hour throughout the day show little temporal variability in tremor severity
- Objectively capturing ET symptoms throughout the day has the potential to help clinicians better titrate therapy to minimize symptoms, expand care to rural and underserved populations, and aid in the evaluation of novel therapies

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