Validity of a Performance-Based Test of Function in Essential Tremor

Elan D. Louis, MD, MS; Kristin J. Wendt, MPH; Steven M. Albert, MS, PhD; Seth L. Pullman, MD; Qiping Yu, PhD; Howard Andrews, PhD

Background: The central factor influencing therapeutic decisions in essential tremor (ET) is the functional impact of the tremor. Neither the neurological examination nor computerized tremor analysis measures function. Questionnaires may assess function, but data are highly subjective. Performance-based tests of functional impairment provide an alternative means with which to assess the functional impact of ET.

Objective: To determine the internal consistency and validity of a performance-based measure of functional impairment in ET.

Methods: Subjects with ET from a community in northern Manhattan, NY, and from a clinic and control subjects each underwent a 2 1/2-hour evaluation including 12 screening questions for ET, a 31-item Tremor Disability Questionnaire to assess the functional impact of tremor, a 26-item Videotaped Tremor Examination that was rated by a neurologist, a 15-item, 10-minute Performance-Based Test, and Quantitative Computerized Tremor Analysis. Internal consistency was assessed with Cronbach α. The correlation between the Performance-Based Test and these other measures of tremor was assessed by means of correlation coefficients (r).

Results: There were 50 ET cases and 51 normal control subjects. The Performance-Based Test was internally consistent (Cronbach α = .92). It also demonstrated validity among cases; the total score correlated with the total number of screening questions answered yes (r = 0.44; P = .001), the total score on the Tremor Disability Questionnaire (r = 0.55; P < .001), the total score on the Videotaped Tremor Examination (r = 0.71; P < .001), and multiple physiological measures recorded during Quantitative Computerized Tremor Analysis.

Conclusions: A valid performance-based test was developed to objectively assess functional capacity in patients with ET. This test would be useful in therapeutic trials, where it would provide an objective means to quantify the functional impact of tremor.

Arch Neurol. 1999;56:841-846
SUBJECTS AND METHODS

CASE SUBJECTS

Subjects with ET were ascertained from 2 sources: the Washington Heights–Inwood community, northern Manhattan, NY, and the Center for Parkinson’s Disease and Other Movement Disorders at Columbia-Presbyterian Medical Center, New York, NY. This approach was chosen to ascertain cases with a broad range of tremor severity, including persons with mild ET who live in a community and who do not seek treatment and those with severe ET who are often seen in clinics.3,4,12,16

Persons with ET who were living in the Washington Heights–Inwood community were already enrolled in a family study of ET and, as part of that study, had been interviewed, examined, and videotaped, and a diagnosis of ET had been independently confirmed by 2 neurologists specializing in movement disorders according to a previously published clinical diagnostic protocol.6,12,17-21

The Center for Parkinson’s Disease and Other Movement Disorders is a referral center for patients with involuntary movement disorders. A computerized database provides clinical information on more than 4000 patients seen between 1983 and 1998. All subjects have been examined by a neurologist who specializes in movement disorders; 302 have been diagnosed as having ET.

CONTROL SUBJECTS

Control subjects, recruited from the same 2 sources as the case subjects, were enrolled to examine the validity of this test within a group of unaffected individuals.

As part of a family study of ET, control subjects who were living in the Washington Heights–Inwood community were matched to ET case subjects by age, sex, and ethnicity; they had been interviewed, examined, and videotaped, and normal findings had been independently confirmed by 2 neurologists.6,12,17-21

Control subjects from the Center for Parkinson’s Disease and Other Movement Disorders were the spouses of the ET case subjects. None of these spouses was seeing a physician for a diagnosis of ET or any other neurological disorder.

STUDY PROCEDURE

Each subject underwent a 2½-hour in-person evaluation by a trained tester (K.J.W.). This examination included evaluation of tremor and evaluation of medical and psychiatric disorders and level of function.

Evaluation of Tremor

The following tests and procedures were used to evaluate tremor (Table 1).

The Tremor Interview and Screening Questionnaire, an 84-item semistructured interview, assessed duration and treatment of tremor.6,12,17-21 It included a previously validated 12-item screening questionnaire for ET.6

The 31-item Tremor Disability Questionnaire assessed the functional impact of tremor and was modeled after methods of Fried et al11,22 (ie, some individuals may not complain of “disability,” but further questioning will disclose a need to modify activities).

For the Videotaped Tremor Examination, the trained tester (K.J.W.) administered and videotaped the examination. A neurologist who specialized in movement disorders (E.D.L.) reviewed the videotape and rated the tremor. Tremor was rated during sustained arm extension, pouring water, drinking water, using a spoon, the finger-to-nose maneuver, and drawing a spiral. These 6 tasks were performed with each arm.6,12,17-21

RESULTS

There were 50 ET case subjects and 51 control subjects (Table 3 and Table 4). Forty-six subjects underwent QCTA (20 ET case subjects and 26 control subjects); the remaining 55 were examined in their homes.

Among the 50 ET case subjects, the total score on the Performance-Based Test correlated with the total number of screening questions answered yes (r = 0.44; P = .001), the total score on the Tremor Disability Questionnaire (r = 0.55; P < .001), the total score on the Videotaped Tremor Examination (r = 0.71; P < .001), and multiple physiological measures recorded during QCTA, including mean distally recorded amplitude of dominant-arm tremor during sustained arm extension (r = 0.73; P < .001), dominant-arm finger-to-nose tremor (r = 0.53; P = .006), dominant-arm tremor while pouring water (r = 0.51; P = .008), and dominant-arm tremor while drawing a spiral (r = 0.89; P < .001).

There was no correlation between total score on the Performance-Based Test and the total scores on the Cumulative Illness Rating Scale (r = −0.05; P = .72), the Modified Mini-Mental State Examination (r = −0.01; P = .95), the Hamilton Anxiety Rating Scale (r = −0.05; P = .76), the State-Trait Anxiety Inventory (r = −0.02; P = .91), the Katz Activities of Daily Living Scale (r = −0.05; P = .73), or the Lawton Instrumental Activities of Daily Living Scale (r = −0.12; P = .41).

To determine whether the severity of tremor influenced the validity of the Performance-Based Test, the 50 ET cases were stratified into 2 groups based on the median of the total score on Videotaped Tremor Examination. Subjects with severe tremor had total scores of 18 or greater; subjects with mild ET had scores less than 18. In subjects with severe tremor, the total score on the Performance-Based Test correlated with the total number of screening questions answered yes, the Tremor Disability Questionnaire total score, the Videotaped Tremor Examination total score, and 3 of the 4 physiological measures recorded during QCTA. In contrast, in subjects with mild tremor, the scores on the Performance-Based Test only correlated with the total number of screening questions answered yes and the Tremor Disability Questionnaire total score.

Among the 51 control subjects, the total score on the Performance-Based Test only correlated with the total score on the Tremor Disability Questionnaire (r = 0.31; P = .01).

Cronbach α was equal to .92, indicating that these items do in fact constitute a strong, internally consistent measure of functional impairment.

©1999 American Medical Association. All rights reserved.
The Performance-Based Test (Table 2) assessed the ability of the subject to perform daily activities. The test was administered and rated by a trained tester (K.J.W.).

The Quantitative Computerized Tremor Analysis (QCTA) was performed by one of us (S.L.P. or Q.Y.) in the Motor Neurophysiology Laboratory at Columbia-Presbyterian Medical Center. The tremor analysis involved the use of ultralight piezoresistive miniature accelerometers (±25 g, 0.5 g) with linear sensitivities of approximately 4.5 mV/g in the physiological range, which were attached to a proximal and a distal position on each arm (distal humerus and the dorsum of the hand at the distal end of the middle metacarpal bone). Silver-silver chloride electromyogram surface electrodes were used to record activity of the flexor carpi radialis and extensor carpi radialis muscles along with the accelerometry. Accelerometric and electromyographic signals were digitized at 500 Hz with the use of a 15-microsecond 16-bit analog-to-digital system and stored in eight 4-second trials during 5 conditions: at rest, arms extended, finger-to-nose movements, pouring water between 2 cups, and drawing spirals. Tremor was sampled during a 30-minute period to record variation over time. Tremor amplitudes were derived off-line by double integration of wrist accelerometric data after filtering out low-frequency drift (<2 Hz) and averaging. Electromyograms were full-wave rectified, integrated, and processed with the accelerometric data.

Evaluation of Medical and Psychiatric Disorders and Level of Function

This evaluation included the Cumulative Illness Rating Scale, Modified Mini-Mental State Examination, Hamilton Anxiety Rating Scale, State-Trait Anxiety Inventory, Katz Activities of Daily Living Scale, and Lawton Instrumental Activities of Daily Living Scale.

Table 1. Characteristics of Tests Used to Evaluate Tremor

<table>
<thead>
<tr>
<th>Ratable Item</th>
<th>No. of Ratable Items</th>
<th>Range of Ratings for Each Ratable Item</th>
<th>Total Possible Score Indicating Least Impairment</th>
<th>Total Possible Score Indicating Most Impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screening Questionnaire*</td>
<td>12</td>
<td>0-1</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Tremor Disability Questionnaire</td>
<td>31</td>
<td>0-2</td>
<td>0</td>
<td>100*</td>
</tr>
<tr>
<td>Videotaped Tremor Examination†</td>
<td>12</td>
<td>0-3</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td>Performance-Based Test</td>
<td>15</td>
<td>0-4</td>
<td>0</td>
<td>100*</td>
</tr>
</tbody>
</table>

* Total possible score converted to a percentage.
†See Table 2 for actual test.

Three factors emerged from the factor analysis (Table 5). Together, these factors explained 68.0% of the total variance. Factor 1 (eigenvalue, 7.33) explained nearly one half (48.9%) of the variance. This factor was composed of 6 items that often involved tasks requiring a great deal of concentration on steadiness and minimization of sudden random movements. These tasks included manipulation of liquids so as not to spill, or fine movements of distal body parts (such as threading a needle or placing keys in a lock). In contrast, factor 3 comprised 3 items that involved large movements characterized by arm extension with the intention of hitting a target. Factor 2 comprised some items that involved writing, although it was difficult to identify an underlying commonality among items within this factor.

On the basis of the results of the factor analysis, we chose 2 test items from each of the 3 factors to create a shorter test that could be administered in less than 5 minutes. Our approach was practical; rather than choosing items with the highest loadings, we chose those that were easy to administer, involved activities that were performed frequently, or involved the fewest test instruments. These were items 9 (place keys in lock), 2 (drink from glass), 6 (copy sentences), 8 (place bills in wallet),

CONFIRMATION OF DIAGNOSES

A neurologist (E.D.L.), unaware of the subject’s identity as a case or control subject, reviewed the Videotaped Tremor Examination and assigned a final diagnosis of normal or ET in each subject on the basis of published criteria. For all ET cases and community-ascertained control subjects, this step represented a confirmation of the diagnosis because diagnoses had previously been assigned to ET cases and control subjects from the community by videotape review and rating, and diagnoses had previously been assigned to ET cases from the clinic by a neurologist at the clinic. If there was diagnostic ambiguity (initial diagnosis was ET but final diagnosis was normal or vice versa), subjects were excluded from these analyses.

INDEPENDENCE OF TESTS

The Performance-Based Test was rated by K.J.W. and the Videotaped Tremor Examination, by E.D.L. The QCTA was independently performed by S.L.P. or Q.Y.

DATA ANALYSIS AND STATISTICS

Pearson correlation coefficient (r) was used to assess the correlation between continuous variables. To determine whether each of the screening questions correlated with one another (internal consistency), Cronbach α was calculated. To determine whether screening questions might be related to a smaller number of underlying factors, a factor analysis was performed by the principal component method with orthogonal (varimax) rotation. The identification of a small number of underlying factors would allow creation of a simplified, shorter screening questionnaire with less redundancy.
1. Pour liquid from a milk carton into a glass. Glass should be resting on a table in front of the subject. Fill the glass to the 95% mark.
2. Drink from a glass of water that is filled to the 95% mark (10 motions from lip to mouth).
3. Use a soup spoon to drink liquid from a bowl. Bowl should be held at lap level (15 motions from lip to mouth).
4. Pick up a 95%-full cup and saucer and carry them 20 ft and then replace on table.
5. Carry a tray with 2 glasses that are each filled to the 95% mark (20 feet).
6. Copy 3 short sentences, keeping letters in predetermined boundaries (6.5 in wide, 1.75 in high). Do not rest arm on table.
7. Sign name. Do not rest arm on table.
8. Place 4 bills consecutively in a wallet without resting either on a table.
9. Place 3 keys of 3 different sizes in 3 locks and unlock the locks. Do not rest arms or locks on table.
10. Place 5 coins of different sizes in a vertical opening in a metal box. Box should be placed on the table in front of subject.
11. Place 1 plug in an electrical socket. Hold the plug and socket in each hand.
12. Correctly dial 15 numbers (1249 8753 5696 258) on a Touch-Tone telephone that is placed on a table.
13. Use 2 flat-head screwdrivers of different lengths to completely screw 2 screws into a metal board. The screwdrivers and the metal board should be held in each hand.
14. Thread 1 needle. Hold the needle and thread in each hand.
15. Button 1 strip of 8 buttons on a shirt. Shirt should be placed in front of subject on a table.

For all items except 4 and 5, subject should be seated in a chair and should use his/her dominant arm:

**Table 2. Performance-Based Test**

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pour liquid from a milk carton into a glass. Glass should be resting on a table in front of the subject. Fill the glass to the 95% mark.</td>
</tr>
<tr>
<td>2</td>
<td>Drink from a glass of water that is filled to the 95% mark (10 motions from lip to mouth).</td>
</tr>
<tr>
<td>3</td>
<td>Use a soup spoon to drink liquid from a bowl. Bowl should be held at lap level (15 motions from lip to mouth).</td>
</tr>
<tr>
<td>4</td>
<td>Pick up a 95%-full cup and saucer and carry them 20 ft and then replace on table.</td>
</tr>
<tr>
<td>5</td>
<td>Carry a tray with 2 glasses that are each filled to the 95% mark (20 feet).</td>
</tr>
<tr>
<td>6</td>
<td>Copy 3 short sentences, keeping letters in predetermined boundaries (6.5 in wide, 1.75 in high). Do not rest arm on table.</td>
</tr>
<tr>
<td>7</td>
<td>Sign name. Do not rest arm on table.</td>
</tr>
<tr>
<td>8</td>
<td>Place 4 bills consecutively in a wallet without resting either on a table.</td>
</tr>
<tr>
<td>9</td>
<td>Place 3 keys of 3 different sizes in 3 locks and unlock the locks. Do not rest arms or locks on table.</td>
</tr>
<tr>
<td>10</td>
<td>Place 5 coins of different sizes in a vertical opening in a metal box. Box should be placed on the table in front of subject.</td>
</tr>
<tr>
<td>11</td>
<td>Place 1 plug in an electrical socket. Hold the plug and socket in each hand.</td>
</tr>
<tr>
<td>12</td>
<td>Correctly dial 15 numbers (1249 8753 5696 258) on a Touch-Tone telephone that is placed on a table.</td>
</tr>
<tr>
<td>13</td>
<td>Use 2 flat-head screwdrivers of different lengths to completely screw 2 screws into a metal board. The screwdrivers and the metal board should be held in each hand.</td>
</tr>
<tr>
<td>14</td>
<td>Thread 1 needle. Hold the needle and thread in each hand.</td>
</tr>
<tr>
<td>15</td>
<td>Button 1 strip of 8 buttons on a shirt. Shirt should be placed in front of subject on a table.</td>
</tr>
</tbody>
</table>

**Table 3. Characteristics of 101 Study Subjects**

<table>
<thead>
<tr>
<th></th>
<th>Community Cases (n = 31)</th>
<th>Clinic Cases (n = 19)</th>
<th>Community Control Subjects (n = 37)</th>
<th>Clinic Control Subjects (n = 14)</th>
<th>Significance (All Cases vs All Control Subjects)</th>
<th>Significance (Community Cases vs Clinic Cases)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>78.6 (6.9)</td>
<td>57.7 (18.8)</td>
<td>79.2 (6.2)</td>
<td>59.1 (10.8)</td>
<td>t = 1.1</td>
<td>t = 5.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P = .13</td>
<td>P &lt; .001</td>
</tr>
<tr>
<td>Sex† No. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>12 (38.7)</td>
<td>11 (57.9)</td>
<td>16 (43.2)</td>
<td>5 (35.7)</td>
<td>x² = 0.6</td>
<td>x² = 1.8</td>
</tr>
<tr>
<td>F</td>
<td>19 (61.3)</td>
<td>8 (42.1)</td>
<td>21 (56.8)</td>
<td>9 (64.3)</td>
<td>P = .69</td>
<td>P = .15</td>
</tr>
<tr>
<td>Ethnicity, No. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>9 (29.0)</td>
<td>18 (94.7)</td>
<td>12 (32.4)</td>
<td>13 (92.9)</td>
<td>x² = 0.5</td>
<td>x² = 20.6</td>
</tr>
<tr>
<td>African American</td>
<td>10 (32.3)</td>
<td>0</td>
<td>13 (35.1)</td>
<td>0</td>
<td>P = .80</td>
<td>P &lt; .001</td>
</tr>
<tr>
<td>Hispanic</td>
<td>12 (38.7)</td>
<td>1 (5.3)</td>
<td>12 (32.4)</td>
<td>1 (7.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years of education, mean (SD)</td>
<td>10.1 (4.7)</td>
<td>16.1 (3.6)</td>
<td>11.1 (4.0)</td>
<td>15.4 (2.4)</td>
<td>F = 0.1</td>
<td>F = 4.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>P = .91</td>
<td>P &lt; .001</td>
</tr>
</tbody>
</table>

*Boldface values are significant.
†M indicates male; f, female.

Appreciation of ET severity is often guided more by the functional impact of tremor than by physical indexes such as tremor amplitude or frequency. Performance-based testing provides valuable information about the functional impact of tremor. The advantage of this method over questionnaires is that data are more objective. In ET, performance-based tests have a particularly important role because, while many individuals may not report “disability,” they have had to make adaptations in the way they perform certain tasks (e.g., using 2 hands, performing tasks more slowly).9,11,34 The development of a performance-based test for ET is important because such a test could be used in clinical-therapeutic trials to quantify the impact of new treatments on function and disability. In addition, such a test could be used in epidemiological studies to document different patterns of functional impairment from tremor within different subgroups (e.g., sex, age) in the population.

Some clinical trials have incorporated brief functional assessments of 1 or 2 test items, variably including ratings of pouring, writing, or drawing; some investigators have included up to 4 items.35-38 However, different trials have not always used the same test items or have not standardized the manner in which these are administered, and this limits comparability between studies. The rationale for choosing one item over another has not been stated. Moreover, there have been few attempts to vali-
date any performance-based measures in patients with ET. Bain et al assessed the correlation between 2 performance-based measures (drawing spirals and writing), clinical ratings of tremor severity, and accelerometric data in 12 patients with ET and found a correlation between these 2 measures and clinical ratings of right-arm tremor, but no correlation between these 2 measures and accelerometric data. Elble et al noted a modest correlation between clinical ratings and accelerometric measurements of tremor amplitude during writing.

We developed a 15-item, 10-minute performance-based test for use in ET research and examined its internal consistency (reliability) and validity. The test was highly internally consistent. The test was also highly valid in the sense that scores correlated with a broad range of tests ranging from subjective to objective and included several questionnaires, a neurologist’s ratings of tremor on a Videotaped Tremor Examination, and multiple physiological measures recorded during QCTA.

Whereas the test was a valid measure of tremor severity in subjects with ET, this was not true for control subjects, in whom the test scores did not correlate with either subjective or objective measures of tremor severity. This implies that the Performance-Based Test accurately assessed true pathological tremor when it was present, but that the scores were not consistently altered by milder or normal forms of tremor as might be present in some control subjects. Even among ET case subjects, the test was more valid among those with more severe tremor than those with mild tremor.

The Performance-Based Test was further assessed by factor analysis, and 3 factors emerged that together explained the majority of the variance in the original test items. These factors may relate to the performance of different types of tasks (eg, fine finger movements, steadying activities, hitting targets). In an attempt to construct a briefer, easy-to-administer version of the test, a 5-minute, 6-item test was constructed. This test was also valid, implying that it could be used as a substitute for the entire questionnaire.

There were limitations. This test assessed dominant-arm function as influenced by kinetic tremor. Tremor in other body areas (eg, nondominant arm, legs, head, or voice) and postural tremor may influence treatment as well. In addition, tremor amplitude may vary considerably under different circumstances, and laboratory-
based performance tests may not reflect the subjects’ level of function when they are in their homes performing other activities of daily living. However, overall, this test provides a valid means with which function in ET may be assessed directly and objectively.

Accepted for publication October 8, 1998.

This study was supported by the Paul Bescos Physician Faculty Scholars in Aging Research Award (American Federation for Aging Research, New York, NY) and grant NS01863 from the National Institutes of Health, Bethesda, Md.

Reprints: Elan D. Louis, MD, MS, Unit 198, Neurological Institute, 710 W 168th St, New York, NY 10032.

REFERENCES