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RESEARCH ARTICLE

Comparison of the Fahn-Tolosa-Marin Clinical Rating Scale and the Essential Tremor Rating Assessment Scale

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Abstract: **Background:** The Fahn-Tolosa-Marin Clinical Rating Scale for Tremor (FTM) has been used in large trials for essential tremor (ET), but its anchors for ratings from 0 to 4 of upper limb tremor are probably too low for patients with severe tremor (tremor amplitude >4 cm; grade 4). The Essential Tremor Rating Assessment Scale (TETRAS) is a validated clinical scale designed specifically for the assessment of ET severity. TETRAS has anchors that span a larger range of tremor amplitudes (>20 cm = grade 4), making it more suitable for assessing patients with severe ET. However, there is no direct comparison of these scales in any clinical trial.

Methods: Upper limb postural and kinetic tremor items from both scales were compared using blinded, video-recorded examinations of patients with moderate-to-severe ET who participated in a trial of focused ultrasound thalamotomy.

Results: FTM ratings of postural and kinetic tremor correlated strongly with those of TETRAS. However, FTM exhibited a ceiling effect for severe tremor. Rest tremor, exclusive to FTM, correlated poorly with postural and kinetic tremor and had very poor test-retest reliability. In contrast, wing-beating postural tremor, exclusive to TETRAS, exhibited excellent test-retest reliability and a strong correlation with kinetic and limbs-extended-forward postural tremor. Test-retest reliabilities of the other TETRAS and FTM ratings were excellent, and both scales had good sensitivity to treatment effect.

Conclusions: TETRAS has 2 main advantages over FTM in the assessment of tremor severity: (1) the absence of a ceiling effect in patients with severe ET, and (2) the inclusion of wing-beating tremor.

Clinical trials for essential tremor (ET) have employed dozens of different scales and assessments as measures of primary efficacy. The most commonly used scale in large trials has been the Fahn-Tolosa-Marin Clinical Rating Scale for Tremor (FTM).[1] The Essential Tremor Rating Assessment Scale (TETRAS) is a more recently validated scale that was designed specifically for the assessment of tremor severity in patients with ET.[2]

Both expert and novice raters perform TETRAS with excellent inter-rater and intra-rater reliability.[3] The reliability of FTM is less established. Large numbers of raters, rating a small sample of patients, found good intra-rater reliability and fair inter-rater reliability for the tremor location/severity items but only fair intra-rater reliability and poor inter-rater reliability for spiral drawing and handwriting ratings.[4] The reliability of the water-pouring task was not assessed.

There are 2 main differences in how upper limb tremor is assessed using these scales. First, the FTM assesses postural tremor in the limbs-extended-forward posture, kinetic tremor in

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the finger-nose-finger reaching task, and rest tremor while both upper limbs are relaxed on the patient's lap, all of which are performed while the patient is seated. TETRAS does not assess rest tremor but does include an assessment of postural tremor in the "wing-beating" position, in which the elbows are flexed and extended laterally with shoulders abducted, such that the upper limbs are held horizontally with the hands in front of the upper chest. Second, the 0 to 4 ordinal ratings of upper limb tremor in TETRAS span a much larger range of tremor amplitudes than the FTM, and 0.5 increments in ratings are used in TETRAS. Grade 4 tremor in TETRAS corresponds to amplitudes greater than 20 cm, whereas grade 4 tremor in FTM corresponds to amplitudes greater than 4 cm. With this expanded amplitude range, TETRAS should exhibit far less ceiling effect in studies of severe ET and could be more sensitive to change. However, this theoretical advantage of TETRAS over the FTM has not been empirically assessed.

A recent systematic review of tremor rating scales found that the FTM and TETRAS are valid scales that are sensitive to change in clinical trials.[5] Both scales correlate well with transducer measures of tremor, and total scores correlate strongly with each other.[3,6] However, there are few additional comparative data, and test-retest reliability estimates are needed for both scales. Therefore, we compared upper extremity tremor ratings between the FTM and TETRAS using video-recorded examinations of 76 patients who participated in a study of focused ultrasound thalamotomy.[7] We hypothesized that FTM ratings would exhibit a ceiling effect for severe ET. We also hypothesized that the wing-beating posture would elicit greater tremor than the limbs-extended-forward posture and possibly would be more sensitive to change. Finally, we computed the test-retest reliability for each of the FTM and TETRAS upper limb ratings used in the videos and for the FTM ratings of drawings and pouring.

Patients and Methods

A 1-year, multicenter, sham-controlled trial recently demonstrated the efficacy of unilateral focused ultrasound thalamotomy in the ventralis intermedius for medically refractory ET.[7] Seventy-six patients were enrolled, and 20 randomized to the sham thalamotomy group. Standardized examinations were video recorded at each visit (at baseline, 1 month, 3 months, 6 months, and 12 months). FTM ratings of the surgically treated upper limb were the primary efficacy measures. However, blinded TETRAS upper limb ratings were also performed. In this study, the video-recorded baseline and 3-month follow-up examinations were used for comparisons of the FTM items versus TETRAS items used in the video assessments.

The video-recorded examinations were rated by 5 of the authors, all members of the Tremor Research Group that developed TETRAS.[2] The 5 raters received training on the video ratings and were tested to be within 1 standard deviation of the mean on 3 practice videos. The raters were blinded to treatment allocation (sham vs. thalamotomy) and side of lesion (left vs. right thalamus) but possibly could infer which video was from the baseline examination, because the head was not yet shaved.

We examined the distributions of FTM versus TETRAS baseline ratings of the treated limbs, looking for evidence of a ceiling effect in the FTM. We also compared the baseline versus 3-month ratings to determine whether 1 scale was more sensitive to treatment effect or showed a greater placebo response. The baseline TETRAS limbs-extended-forward and wing-beating ratings were compared to determine whether 1 posture elicited greater tremor and responsiveness to treatment. We estimated test-retest reliability of all FTM and TETRAS ratings of the untreated limbs (baseline vs. 3 months; N = 76) using 2-way-random, single-measure intraclass correlations. We computed Cronbach α values to determine the internal consistency of upper limb ratings in FTM and TETRAS, and we examined the correlations of FTM and TETRAS ratings against a composite sum of the FTM water-pouring and drawing (spirals and lines) scores. Cohen's d effect size was computed with pooled standard deviations. Statistical analyses were performed with the MedCalc software package (MedCalc Software, Ostend, Belgium; www.medcalc.org).

Results

Baseline FTM and TETRAS limbs-extended-forward postural and finger-nose-finger kinetic upper extremity tremor scores are summarized in Table 1 for the 76 upper limbs in patients in the thalamotomy group (N = 56) and those in the sham thalamotomy group (N = 20). All were normally distributed (D'Agostino-Pearson test). FTM rest tremor was not normally distributed, because only 11 of 76 upper limbs in the thalamotomy group or the sham thalamotomy group exhibited rest tremor at baseline, and only 5 of the 76 untreated limbs had rest tremor.

The TETRAS wing-beating posture produced greater baseline tremor than the limbs-extended-forward posture (t = 5.09; degrees of freedom [df], 75; $P < 0.0001$) (Table 1). TETRAS wing-beating tremor was also slightly greater than TETRAS kinetic tremor (t = 1.99; df 75, $P = 0.05$). TETRAS and FTM postural and kinetic tremor ratings were strongly correlated (postural $r = 0.92$, kinetic $r = 0.84$, $P < 0.0001$). FTM rest tremor had poor Spearman correlations (ρ) with FTM postural tremor ($\rho = 0.23$; $P = 0.003$) and kinetic tremor ($\rho = 0.21$; $P = 0.01$).

TETRAS and FTM measures of postural tremor with limbs extended forward exhibited a comparable floor effect, but there was no significant floor effect for TETRAS or FTM measures of kinetic tremor (Fig. 1). By contrast, FTM kinetic tremor and postural tremor exhibited a ceiling effect, but TETRAS did not (Fig. 1).

Compared with baseline, a statistically significant treatment effect of thalamotomy was detected at 3 months with all FTM and TETRAS items used in the study (Table 2), even when the P values were Bonferroni adjusted for 12 comparisons (5% significance level, $P < 0.004$). All items except FTM rest tremor had very large Cohen's d effect sizes (Table 2). Because FTM

TABLE 1 Descriptive statistics for postural and kinetic tremor scores on the Fahn-Tolosa-Marin Clinical Rating Scale for Tremor and the Essential Tremor Rating Assessment Scale at baseline*

Item	No.	Mean	95% CI	SD	SEM	Median	95% CI	*P* (Normality)†
FTM postural	76	2.00	1.73–2.27	1.18	0.14	2.00	2.00–2.00	0.20
FTM kinetic	76	2.32	2.13–2.50	0.82	0.09	2.00	2.00–2.00	0.74
TETRAS postural	76	1.80	1.59–2.02	0.93	0.11	2.00	1.50–2.00	0.21
TETRAS wing-beating	76	2.28	2.07–2.48	0.88	0.11	2.50	2.00–2.50	0.27
TETRAS kinetic	76	2.09	1.95–2.24	0.63	0.07	2.00	2.00–2.00	0.19

Abbreviations: CI, confidence interval; SD, standard deviation; SEM, standard error of the mean; FTM, Fahn-Tolosa-Marin Clinical Rating Scale for Tremor; TETRAS, the Essential Tremor Rating Assessment Scale.
*The 95% confidence limits are given for the mean and median values.
†*P* values are shown for the D'Agostino-Pearson test of normality (normality is accepted when $P > 0.05$).

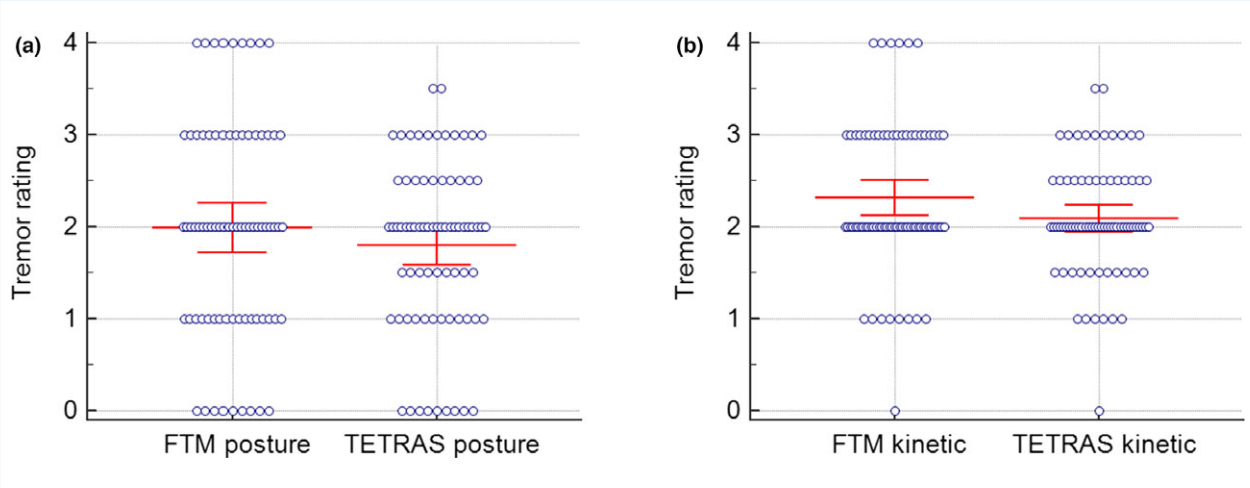

FIG. 1. Comparison of baseline (*Left*) postural and (*Right*) kinetic ratings on the Fahn-Tolosa-Marin Clinical Rating Scale for Tremor (FTM) and the Essential Tremor Rating Assessment Scale (TETRAS) for the upper limbs treated with thalamotomy or sham (N = 76). The means and 95% confidence intervals are also shown.

rest tremor was not normally distributed, we also computed the effect size of FTM rest tremor by dividing the standard normal deviate z from the Wilcoxon analysis by the square root of 2N, producing an effect size of 0.22. The effect sizes for FTM postural and kinetic tremor items did not differ statistically from the postural, wing-beating, and kinetic items of TETRAS. The poor performance of the FTM rest tremor item can be explained by the fact that only 9 of the 56 limbs in the thalamotomy group had a rest tremor rating greater than zero. The change (from baseline to 3 months) in TETRAS composite scores (postural + wing beating + kinetic tremor: mean score, 3.61; 95% confidence interval [CI], 3.00–4.21) caused by thalamotomy was greater than the change in FTM composite scores (rest + postural + kinetic tremor: mean score, 2.84; 95% CI, 2.34–3.34; t = 4.21; df, 55; $P < 0.0001$), and this too can be explained by the absence of rest tremor in most patients.

For all FTM and TETRAS items, the change at 3 months was statistically nil for the sham-treated limbs (Table 3). Thus, there was no evidence of a placebo effect using FTM or TETRAS.

Baseline versus 3-month test-retest intraclass correlations for the untreated limbs were ≥0.74 for all tremor measures except FTM rest tremor, which was only 0.01. Test-retest intraclass correlations were also excellent for the TETRAS and FTM composite scores (0.87 and 0.81, respectively), (Table 4).

Cronbach α values for the TETRAS postural, wing-beating, and kinetic tremor ratings were greater than those for the FTM rest, postural, and kinetic tremor ratings (0.83 vs. 0.64, respectively) (Table 5). This was largely due to the poor correlation of FTM rest tremor with postural and kinetic tremor (Table 5). By contrast, Cronbach α values for the TETRAS upper limb ratings decreased significantly when the wing-beating postural tremor item was omitted (Table 5). Cronbach α values for the FTM drawing and pouring tasks improved significantly when pouring was omitted (Table 5).

Both TETRAS and FTM composite upper limb scores were significantly correlated with the sum of FTM drawing (spiral A + spiral B + lines) and pouring scores (TETRAS, $r = 0.73$; FTM, $r = 0.67$; $P < 0.0001$ for both; baseline data for all upper limbs, N = 152). The TETRAS and FTM composite scores also were strongly correlated ($r = 0.9$; N = 152; $P < 0.0001$).

Discussion

There was strong a correlation between FTM and TETRAS ratings of upper extremity postural and kinetic tremors.

TABLE 2 Comparison of scores on the Fahn-Tolosa-Marin Clinical Rating Scale for Tremor and the Essential Tremor Rating Assessment Scale at baseline and at 3 months

		Baseline		3 Months		Paired Differences[a]				Effect Size	95% CI
Item	No.	Mean	SD	Mean	SD	Mean	SD	95% CI	P^b		
FTM kinetic	56	2.43	0.85	1.25	0.10	1.18	0.96	0.92–1.43	<0.0001	1.27	0.94–1.61
FTM postural	56	2.13	1.15	0.64	0.94	1.48	1.19	1.16–1.80	<0.0001	1.41	1.00–1.80
FTM rest	56	0.30	0.76	0.13	0.51	0.18	0.54	0.03–0.32	0.0170	0.28	0.06–0.50
FTM composite[c]	56	4.86	2.02	2.02	1.89	2.84	1.88	2.34–3.34	<0.0001	1.45	0.96–1.84
Lines	56	2.91	0.72	1.82	0.88	1.09	0.88	0.85–1.32	<0.0001	1.36	1.00–1.71
Pouring	56	2.32	1.08	1.09	1.01	1.23	1.18	0.92–1.55	<0.0001	1.18	0.84–1.53
Spiral A	56	2.86	0.90	1.68	0.94	1.18	1.03	0.90–1.45	<0.0001	1.28	0.94–1.65
Spiral B	56	3.09	0.79	1.91	0.92	1.18	1.03	0.90–1.45	<0.0001	1.37	0.97–1.75
TETRAS kinetic	56	2.14	0.67	1.22	0.82	0.92	0.77	0.71–1.13	<0.0001	1.23	0.93–1.53
TETRAS postural	56	1.89	0.86	0.62	0.87	1.27	0.99	1.00–1.53	<0.0001	1.47	1.00–1.91
TETRAS wing-beating	56	2.39	0.89	0.97	1.04	1.42	0.98	1.16–1.68	<0.0001	1.47	1.09–1.81
TETRAS composite[d]	56	6.42	1.93	2.81	2.11	3.61	2.26	3.00–4.21	<0.0001	1.78	1.40–2.17

Abbreviations: SD, standard deviation; CI, confidence interval; SEM, standard error of the mean; FTM, Fahn-Tolosa-Marin Clinical Rating Scale for Tremor; TETRAS, the Essential Tremor Rating Assessment Scale.
[a]Paired differences are shown for baseline versus 3-month ratings.
[b]*P* values were determined using the paired t test.
[c]FTM composite = rest + postural + kinetic scores.
[d]TETRAS composite = postural + wing-beating + kinetic scores.

TABLE 3 The effect of sham surgery at 3 months compared with baseline

		Baseline		3 Months		Paired Differences[a]			
Measure	No.	Mean	SD	Mean	SD	Mean	SD	95% CI	P^b
FTM kinetic	20	2.00	0.65	2.10	0.45	−0.10	0.72	−0.44, 0.24	0.55
FTM postural	20	1.65	1.23	1.85	1.04	−0.20	1.06	−0.69, 0.29	0.41
FTM rest	20	0.25	0.79	0.30	0.80	−0.05	0.22	−0.16, 0.05	0.33
FTM location	20	3.90	1.89	4.25	1.68	−0.35	1.42	−1.02, 0.32	0.29
Lines	20	2.80	0.70	2.55	0.83	0.25	0.55	−0.01, 0.51	0.06
Pouring	20	2.05	1.05	2.05	0.94	0.00	0.65	−0.30, 0.30	1.00
Spiral A	20	2.60	1.05	2.45	0.83	0.15	0.93	−0.29, 0.59	0.48
Spiral B	20	3.05	0.69	2.95	0.83	0.10	0.55	−0.16, 0.36	0.43
TETRAS kinetic	20	1.95	0.51	1.90	0.39	0.05	0.56	−0.22, 0.32	0.69
TETRAS postural	20	1.58	1.10	1.73	0.94	−0.15	0.84	−0.55, 0.25	0.44
TETRAS wing-beating	20	1.95	0.81	2.00	0.90	−0.05	0.76	−0.41, 0.31	0.77
TETRAS location	20	5.48	2.12	5.63	1.99	−0.15	1.70	−0.95, 0.65	0.61

Abbreviations: SD, standard deviation; CI, confidence interval; FTM, Fahn-Tolosa-Marin Clinical Rating Scale for Tremor; TETRAS, the Essential Tremor Rating Assessment Scale.
[a]Paired differences are shown for baseline versus 3-month ratings.
[b]*P* values were determined using the paired t test.

TETRAS ratings of upper limb tremor tended to be lower than FTM ratings because of the lower amplitude ranges for FTM ratings of 0 to 4. FTM postural and kinetic ratings exhibited a ceiling effect that will become increasingly evident when patients with greater tremor severity are studied. Postural and kinetic tremor ratings for both scales had floor effects, which will be important when tremor is mild.

FTM and TETRAS ratings of postural and kinetic tremor had comparable sensitivity to the robust clinical improvement produced by focused ultrasound thalamotomy. However, because of the ceiling effect of its anchors, FTM would not be expected to perform as well in a patient population with greater tremor severity, especially when there is a smaller treatment effect. The relative sensitivity of FTM versus TETRAS to the effect of less robust interventions in patients with mild-to-moderate ET is not known, but significant differences between FTM and TETRAS are unlikely, because the anchors of the ratings from 0 to 4 of FTM are very similar to the ratings from 0 to 2.5 (in 0.5 increments) of TETRAS.

The developers of TETRAS included an assessment of upper limb tremor in the wing-beating posture and omitted an assessment of rest tremor. This was done because rest tremor is rarely a source of disability in ET and because it was the anecdotal experience of the authors of TETRAS that the wing-beating posture frequently elicited more tremor than the limbs-extended-forward posture. These impressions were confirmed in the current study. The wing-beating item in TETRAS clearly outperformed the FTM rest tremor item in the assessment of ET severity. The wing-beating posture produces tremor that is comparable to finger-nose-finger kinetic tremor and that greater than postural tremor with limbs extended forward. The test-retest reliability of rest tremor in ET was essentially zero in this study, and FTM rest tremor correlated poorly with postural and kinetic tremor. Cronbach α values for the FTM rest, postural, and kinetic tremor ratings improved greatly when

TABLE 4 Baseline versus 3-month test-retest reliability of items on the Fahn-Tolosa-Marin Clinical Rating Scale for Tremor and the Essential Tremor Rating Assessment Scale*

Item(s)	Intraclass Correlation†	95% Confidence Limits
FTM items		
Kinetic tremor	0.79	0.69–0.86
Postural tremor	0.74	0.62–0.83
Rest tremor	0.01	−0.21, 0.24
Kinetic + postural + rest tremor composite score	0.81	0.71–0.88
Large spiral A drawing	0.76	0.65–0.84
Small spiral B drawing	0.82	0.74–0.89
Drawing straight lines	0.80	0.70–0.87
Pouring	0.74	0.62–0.83
Spirals + lines + pouring composite score	0.88	0.82–0.93
TETRAS items		
Kinetic tremor	0.78	0.68–0.86
Postural tremor	0.75	0.63–0.83
Wing-beating tremor	0.82	0.71–0.89
Kinetic + postural + wing-beating tremor composite score	0.87	0.79–0.92

Abbreviations: FTM, Fahn-Tolosa-Marin Clinical Rating Scale for Tremor; TETRAS, the Essential Tremor Rating Assessment Scale.
*Computations were made using the ratings of the untreated limbs (N = 76).
†Two-way-random single measures were used for intraclass correlations (absolute agreement).

TABLE 5 Cronbach alpha analysis of composite tremor scores on the Fahn-Tolosa-Marin Clinical Rating Scale for Tremor and the Essential Tremor Rating Assessment Scale*

Item	Alpha	Change
FTM spirals + lines + pouring tremor composite score		
Cronbach α	0.92	
95% lower confidence limit	0.90	
Variable dropped		
Spiral A (large spiral)	0.87	0.05
Spiral B (small spiral)	0.88	−0.04
Lines	0.88	−0.04
Pouring	0.95	0.03
FTM kinetic + postural + rest tremor composite score		
Cronbach α	0.64	
95% lower confidence limit	0.55	
Variable dropped		
Kinetic tremor	0.36	−0.28
Postural tremor	0.32	−0.32
Rest tremor	0.75	0.11
TETRAS kinetic + postural + wing tremor composite score		
Cronbach α	0.83	
95% lower confidence limit	0.79	
Variable dropped		
Kinetic tremor	0.83	0.00
Postural tremor	0.75	−0.09
Wing–beating tremor	0.70	−0.14

Abbreviations: FTM, Fahn-Tolosa-Marin Clinical Rating Scale for Tremor; TETRAS, the Essential Tremor Rating Assessment Scale.
*All analyses were performed using the baseline scores of both upper limbs (N = 152) of all participants.

rest tremor was omitted. If done, the assessment of rest tremor in ET should be performed in a way that ensures that the upper limbs are at rest.[8] In some of the videos, the forearms were pronated, producing postural tremor, not rest tremor.

A water-pouring task was not included in TETRAS because the developers viewed this task as messy and not necessary for a good assessment of tremor severity. Our Cronbach α analysis of the FTM spirals, lines, and pouring ratings revealed that the exclusion of pouring increased the α value. Moreover, pouring was not more responsive to change than the TETRAS items. These results support our decision not to include pouring in TETRAS.

In conclusion, TETRAS has 2 major advantages over FTM in the assessment of tremor severity in ET: (1) the absence of a ceiling effect in patients with severe tremor, and (2) the inclusion of an assessment of wing-beating tremor. The exclusion of rest tremor could also be viewed as an advantage of TETRAS in the assessment of ET. However, the FTM assessment of rest tremor may be relevant to other forms of tremor. For example, the FTM may be of greater value in the assessment of Holmes tremor and Parkinson tremor, in which rest tremor is a cardinal feature. Nevertheless, the limited amplitude range of tremor anchors in FTM is a disadvantage in the assessment of severe tremor. These results support the use of TETRAS over FTM in studies of ET severity, especially when tremor is severe.

Author Roles

1. Research Project: A. Conception, B. Organization, C. Execution; 2. Statistical Analysis: A. Design, B. Execution, C. Review and Critique; 3. Manuscript Preparation: A. Writing the First Draft, B. Review and Critique.

W.O.: 1A, 1B, 1C, 2A, 2B, 2C, 3A, 3B
V.H.: 1B, 2B
P.A.L.: 1B, 3B
R.P.: 1B, 3B
L.S.: 1B, 3B
T.Z.: 1B, 3B
D.T.: 1B, 3B
R.E. 1A, 1B, 2B, 3B

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Supporting Information

Additional Supporting Information may be found online in the supporting information tab for this article:

Table S1. Descriptive Comparison of the FTM and TETRAS for Postural and Kinetic Upper Limb Tremor (All Treated and Untreated Limbs, all Assessments) as a Function of FTM Integer Scores