Measures of dispersion of WCs EMG waveforms variability: A study with automatic multi-channel guided low-cost high-speed electromyography

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Abstract
Electromyography is very much useful in the identification of target muscles for injecting the drug such as botulinum toxin This study showed significant quantifiable EMG differences in the muscle's signals seen while writing with the right and left hands between those writer's cramp patients with concordant mirror movements (C group) versus those with discordant mirror movements (D group). This was mainly seen in the measures of dispersion of the signal i.e., standard dispersion, variances and their ratio (F-ratio). These were statistically significantly different between the two groups, C and D, and the pattern of differences were consistent with the hypothesis that the discordant group had a compensatory force which overcame the dystonic force resulting in the final abnormal posture. This was seen in the form of larger variances and standard differences in the RHWS in the D group as compared to the C group, as the dystonic and compensatory forces both contribute to the instability. These differences were robust and seen in every measure of dispersion, such as in the patterns of significance of f-values for ratios of variances.

Keywords: Electromyography, human nervous system, neuromuscular control system, Concordant, discordant, measures of dispersion, mean, standard deviation, student t-test, Fisher`s f-test, variance.

Introduction
Writer's cramp is one of the coarsest focal dystonia`s which was described 200 years prior to the primary torsion dystonia. One of the earliest references dates back to 1713, when Ramazinni described it in his book De Morbis Artificum "An acquaintance of mine, a notary by profession, still living, used to spend his whole life continually engaged in writing, and he made a good deal of money from it; primary he instigated to protest of penetrating tiredness in the entire arm, nevertheless no therapy could discharge this, and decisively the entire dominant right arm became entirely incapacitated and petrified. In order to offset this malady, he began to train himself to write with the left hand, but it was not very long before it too was attacked by the same malady."[1-7] However, with the introduction of the computers, sophisticated computers programmes helped to identify the target muscles so as to inject the drug in to those paralyzed muscles. Since then the disease has come down drastically and today writer`s cramp is not a big deal to diagnose both clinically and diagnostically in most of the clinical diagnostic hospital environments both in rural and in urban areas.

EMG Writer`s cramp data acquisition
The data was acquired through the indigenously built multi-channel electromyography (EMG) system by using the innocuous micro electrodes.

Methods and Materials
The data used in this study was writer`s cramp electromyographic data acquired during the patient writing by sitting in a revolving chair. The following techniques are applied, namely Indigenously built multichannel EMG system with required specifications Function generators, signal generators, pulse generators, oscilloscopes, Writer`s cramp EMG data Measures of dispersion, means and standard deviations Variances.
Pearson`s correlation, t-Test, f-Test, etc

Results and discussion
Measures of dispersion of emg waveforms variability
In respect of variability, as reflected in the variances (Table 12), and standard deviations (σ) (Table 13, see given below), the results were highly significant.

Table1: *Variances* (ρ) for the muscles of the * RHWS and *LHWS

RHWS						LHWS					
Patient	**ECR**	**ECU**	**FCR**	**FCU**	**5th Muscle**	**ECR**	**ECU**	**FCR**	**FCU**	**5th Muscle**	**Group**
A1	0.6117	0.6993	0.8985	1.8732	0.3456	0.4682	0.0148	0.0186	0.0149	0.0567	D
A2	1.8419	0.1091	0.1504	0.3693	2.2017	0.1372	0.0727	0.0730	0.0345	0.1020	C
A3	0.0906	0.1192	0.0045	0.0033	0.0468	0.7866	34.5112	0.2662	0.3154	1.1411	C
A4	0.0255	0.0284	0.0605	0.7325	0.3175	0.0248	0.0272	0.0657	0.8396	0.3028	C
A5	0.1009	0.0010	0.1003	0.0963	0.2708	0.0779	0.0009	0.1372	0.1337	0.2420	C

A6	0.3946	0.1281	0.0434	0.0601	0.6068	0.0780	0.0168	0.0037	0.0058	0.0911	C
A7	1.2677	0.8288	4.1287	0.4483	1.7770	0.3534	0.1265	1.8446	0.2065	0.4541	D
A8	0.0878	0.0777	0.0575	0.0529	0.1621	0.0689	0.8995	0.0076	0.0288	0.0729	C
A9	0.3942	49.9379	0.4166	40.0484	0.7668	0.2015	0.3899	0.6874	92.7771	0.3551	C
A10	1.3443	1.5079	3.3701	0.1993	1.8201	0.0679	0.0178	0.0042	0.0077	0.0249	C
A11	0.6020	0.6690	0.3628	0.3914	1.0968	0.0218	0.0084	0.0012	0.0814	0.0087	D
A12	3.7208	0.5234	0.4432	0.2027	5.4190	0.1048	0.0116	0.0049	0.0236	0.0238	D

RHWS = Right Hand Writing Signal; LHWS = Left Hand Writing Signal; D = Discordant
In contrary to the results obtained previously, in respect of variability, the situations differ. Variances are considerably different in all patients muscle. Standard deviations (σ) are considerably different in RHW signals and in LHW signals in all muscles of all patients.

Table 2: Standard deviations (σ) for the muscles of the * RHWS and * LHWS

RHWS						**LHWS**				
ECR	**ECU**	**FCR**	**FCU**	**5th Muscle**	**ECR**	**ECU**	**FCR**	**FCU**	**5thMuscle**	**Group**
78.2105	83.6222	94.7897	136.8637	58.7909	68.4257	12.1614	13.6556	12.2063	23.8064	D
135.7168	33.0252	38.7869	60.7711	148.3805	37.0456	26.9627	27.0231	18.5623	31.9381	C
30.0932	34.5291	6.7160	5.7781	21.6362	88.6930	587.4627	51.5905	56.1644	106.8228	C
15.9553	16.8447	24.5901	85.5855	56.3458	15.7348	16.4854	25.6264	91.6277	55.0263	C
31.7613	3.2240	31.6642	31.0245	52.0399	27.9022	3.0291	37.0453	36.5593	49.1953	C
62.8191	35.7863	20.8390	24.5096	77.8986	27.9319	12.9541	6.0837	7.5939	30.1834	C
112.5920	91.0389	203.1924	66.9524	133.3029	59.4513	35.5726	135.8143	45.4455	67.3901	D
29.6324	27.8682	23.9776	22.9927	40.2660	26.2441	94.8414	8.7115	16.9850	26.9926	C
62.7836	706.6673	64.5451	632.8378	87.5694	44.8887	62.4380	82.9101	963.2089	59.5942	C
115.9446	122.7971	183.5791	44.6448	134.9110	26.0492	13.3398	6.4739	8.7654	15.7783	C
77.5867	81.7915	60.2309	62.5639	104.7287	14.7603	9.1856	3.4209	28.5349	9.3013	D
192.8936	72.3439	66.5705	45.0253	232.7867	32.3755	10.7574	6.9778	15.3709	15.4139	D

* RHWS = Right Ha nd Writing Signal; LHWS = Left Hand Writing Signal; D = Discordant
In most cases, right hand writing signal 'RHWS' variability is markedly higher than the corresponding LHWS variability (Table 14, see given below).

Table 3: *Variances* of the 5 RHWS and 5 LHWS, their *f - ratios* and their *p - values**

Patient A1:	0.6117	0.6993	0.8985	1.8732	0.3456	RHWS/L
	0.4682	0.0148	0.0186	0.0149	0.0567	HWS
	1.3064	47.2800	48.1840	125.7214	6.0986	D
	0	0	0	0	0	Variances (ρ)
	1.8419	0.1091	0.1504	0.3693	2.2017	f-ratios
Patient A2:	0.1372	0.0727	0.0730	0.0345	0.1020	p-values
	13.4213	1.5003	2.0602	10.7184	21.5842	
	0	0	0	0	0	
	0.0906	0.1192	0.0045	0.0033	0.0468	
Patient A3:	0.7866	34.5112	0.2662	0.3154	1.1411	
	0.1151	0.0035	0.0169	0.0106	0.0410	
	1.0000	1.0000	1.0000	1.0000	1.0000	
	0	0	0	0	0	
Patient A5:	0.1009	0.0010	0.1003	0.0963	0.2708	C
	0.0779	0.0009	0.1372	0.1337	0.2420	
	1.2957	1.1328	0.7306	0.7201	1.1190	
	0	0	1.0000	1.0000	0	
Patient A6:	0.3946	0.1281	0.0434	0.0601	0.6068	C
	0.0780	0.0168	0.0037	0.0058	0.0911	
	5.0580	7.6317	11.7334	10.41696	.6608	
	0	0	0	0	0	
Patient A7:	1.2677	0.8288	4.1287	0.4483	1.7770	D
	0.3534	0.1265	1.8446	0.2065	0.4541	
	3.5867	6.5497	2.2383	2.1705	3.9128	
	0	0	0	0	0	

Patient A8:	0.0878	0.0777	0.0575	0.0529	0.1621	C
	0.0689	0.8995	0.0076	0.0288	0.0729	
	1.2749	0.0863	7.5757	1.8325	2.2253	
	0	1.0000	0	0	0	
Patient A9:	0.3942	49.9379	0.4166	40.0484	0.7668	C
	0.2015	0.3899	0.6874	92.7771	0.3551	
	1.9562	128.0950	0.6061	0.4317	2.1592	
	0	0	1.0000	1.0000	0	
Patient A10:	1.3443	1.5079	3.3701	0.1993	1.8201	C
	0.0679	0.0178	0.0042	0.0077	0.0249	
	19.8113	84.7378	804.1067	25.9417	73.1100	
	0	0	0	0	0	
Patient A11:	0.6020	0.6690	0.3628	0.3914	1.0968	D
	0.0218	0.0084	0.0012	0.0814	0.0087	
	27.6304	79.2863	309.9906	4.8072	126.7772	
	0	0	0	0	0	
Patient A12:	3.7208	0.5234	0.4432	0.2027	5.4190	D
	0.1048	0.0116	0.0049	0.0236	0.0238	
	35.4979	45.2259	91.0170	8.5805	228.0829	
	0	0	0	0	0	

* Based on 29999 degrees of freedom. D=Discordant group., C = Concordant group, *p - values* near to 1 indicate that RHWS variance is significantly smaller than the corresponding LHWS variance. For all patients, the first row values are meant for RHW signals, second row meant for LHW signals, third row values are meant for *f-ratios*, and fourth row values are meant for their corresponding p-values. The Variances of the 5 RHWS and 5 LHWS, their f - ratios and their *p values* are significantly different.

(The only major exception is patient A3 whose LHWS variances are markedly greater than the RHWS variances). This is most probably due to the right hand muscles contracting more actively during writing than mirror movements.

It may be noted that the numerical values of *F-ratios* are often found to be near '1' but since the variances are estimated with 29999 degrees of freedom (df), they have a very low standard error (SD of means of many samples of patients) and hence, are effectively, equal to the 'actual' parameter value and hence they are statistically different from one another. However, a range of f-values in the interval 0.4 to 0.25 can be treated as indicating equality of variances while an $f > 2.5$ as indicating right (Rt) variance > left (Lt) variance and an $f > 0.4$ as indicating Rt variance < Lt variance. These are represented in Table J (see given below).

Table 4 : Patterns of significance of *f-values* for the *ratio of variances*

Patient	ECR	ECU	FCR	FCU	5th Muscle	Group
A1	0	1	1	1	1	**D
A2	1	0	0	1	1	
A3	-1	-1	-1	-1	-1	
A4	0	0	0	0	0	
A5	0	0	0	0	0	
A6	1	1	1	1	1	
A7	1	1	0	0	1	D
A8	0	-1	1	0	0	
A9	0	1	0	0	0	
A10	1	1	1	1	1	
A11	1	1	1	1	1	D
A12	1	1	1	1	1	D

* 1 indicates the RHWS variance is significantly higher than the LHWS variance, 0 indicates that the two variances can be accepted as essentially equal to one another, –1 indicates that RHWS variance is significantly smaller than the LHWS variance. ** D = Discordant group

Considering the 5th muscle only, and comparing the ratios of variances, the findings may be summarized in Table K (see given below).

Table 5: Frequency of ratio of variances in 5th muscle

Group		R ≤L	R >L	
C		5	3	8
D		0	4	4
		5	7	12

$\chi^2 \cong 4.2857$ for 1 df, which significant at 5% with p = 0.0383

Table 6: Frequency of ratio of variances of all muscles

Group	R<L	R=L	R>L	
C	6	16	18	40
D	0	3	17	20
	6	19	17	60

with a $\chi^2 \cong$ **9.2857** with 2 df, highly significant at 5% with p = 0.0095 highly significant.

A likely explanation is that in the RHWS and LHWS, the D group has an increased variability in muscle activity in both the dystonic and compensatory forces compared to the C group (where the compensatory force is less) (wide supra – HYPOTHESIS), in right hand writing in the D group, but not so in the C group). This could spread in the form of an overflow phenomenon to the 5th muscles (chosen on the basis it being discordant in the MM) and this increased variance be seen as r > l (right greater than left) in the entire D group in the 5th muscle as, well as in all muscles combined.

Thus, on clinical basis, taking the performance of the 5th muscles only, the Discordant group almost exclusively shows much larger variations in the RHWS 5th muscle than in the LHWS 5th muscle, though the Concordant patients have only 50:50 chance of showing such a behavior. Stated in other words, a ratio of right and left 5th muscle variances being less than 1 is usually indicative that the patient shows Concordant behavior, while a further 'follow-up', with other supplementary evidence is needed for such a classification if it is the other way round.

F-ratio

All patients except A3 show a higher variability in RHWS than in the LHWS, of M5, this exception being highly significant. It has already been pointed out that the F-ratio for 5th muscle can be of some use in 'differential classification'. However, an examination of the overall picture is to be worth attempting, since in quite a few cases, the ratios are considerably large (>>1) or considerably small (<< 1). Taking value of F-ratio between 0.4 and 2.5 as effectively 1, one gets the table mentioned earlier.

Patterns of F-ratio for the 5th muscle between the D and C groups have already been examined. One can now compare the overall patterns of F-ratios between C and D groups, taking all the 5 muscle pairs into consideration.

Conclusion

This study showed significant quantifiable EMG differences in the signals seen while writing with the right and left hands between those writer's cramp patients with concordant mirror movements (C group) versus those with discordant mirror movements (D group). This was mainly seen in the measures of dispersion of the signal i.e., standard dispersion, variances and their ratio (F-ratio).

These were statistically significantly different between the two groups, C and D, and the pattern of differences were consistent with the hypothesis that the discordant group had a compensatory force which overcame the dystonic force resulting in the final abnormal posture. This was seen in the form of larger variances and standard differences in the D group as compared to the C group, as the dystonic and compensatory forces appeared to contribute to the instability.

Source of Funding

None.

Conflict of Interest

None.

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How to cite: Raju VR, Rani BK, Srinivas K, Rao M.V,Patra R K,. Madhukar G, Reddy A, et al. BoTox in writer's cramp: Measures of dispersion of WCs EMG waveforms variability: A study with automatic multi-channel guided low-cost high-speed electromyography *IP Int J Aesthet Health Rejuvenation* 2021;4(3):.