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Research Article

A Clinico-Statistical Analysis of Writer`s Cramp Signals: Study with Indigenously Developed Multi-Channel Intramuscular EMG

Venkateshwarla Rama Raju[1,2,3,4,5]*, Rupam Borgohain[2] and Rukmini Kandadai Mridula[2]

[1]CMR College of Engineering and Technology, Department of Computer Science and Engineering, Kandlakoya, Medchal, Hyderabad, India
[2]Nizam`s Inst of Medical Sciences, Biomedical, Neurology and Neurosurgery Department, Hyderabad, India
[3]Visiting Faculty, Biomedical Engineering Department, Osmania University College of Engineering (Autonomous), OU, India
[4]Malla Reddy Institute of Medical Sciences (MRIMS), Hyderabad, India
[5]Malla Reddy Medical College for Women (MRMC), Hyderabad, India

***Corresponding Author:** Venkateshwarla Rama Raju, CMR College of Engineering and Technology, Department of Computer Science and Engineering, Kandlakoya, Medchal, Hyderabad, India.

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Abstract

We investigated the hand muscles of Dystonia Writer`s cramp (WC) subjects affected due to DYT1 gene mutations in the brain. In clinical environments WC is done subjectively and lacking the objective method. Therefore, the aim of the study is to determine if there is a quantifiable EMG difference in Writer's Cramp (WC) patients with concordant mirror movements (MMs) from those with discordant MMs. For this, the five innocuous intramuscular microelectrodes (100μ) are passed through five-muscles of intrinsic right-hand (RH). The EMG signals are acquired concurrently from flexor aspect of five fore arm muscles using indigenously built multi-channel EMG while subject writing with right-hand (RH), and with intrinsic left-hand. A canonical correlation-analysis between right-hand writing signal (RHWS) and left hand writing signals (LHWS) for each subject was carried out; giving squared canonical correlations. Correlations, for each subject between the signals when inscribing firstly with RH and then with LH are specified. Though, correlations are mostly negligible, albeit, some correlations are quite significant and distinctly high. These are presented as a Table of significant-correlations, i.e., correlations which are greater than 0.50 in absolute-value. It is found that often, the same muscle pairs will have significant correlation with same sign, in both ‗hand signals' (i.e., RHWS, LHWS). In our computation, the scatter plot showed first two principal component (PC) scores explaining about 80% of variation. However, these findings are to be cross— validated with clinical findings on the same subjects.

Keywords: Electromyography; Writer`s Cramp; Dystonia

Introduction

Electromyography

Electromyography (EMG) is a complex signal arising during muscle contraction. Its characteristics are affected by many factors including diseases, such as Limb girdle dystrophy, repetitive strain injury syndrome, Writer`s cramp`s, Musicians Cramp, etc [1,2]. The EMG signal looks very noisy with complex interference patterns (immersed) but indeed is highly structured. In neurology, EMG is performed for nerve conduction studies and muscle testing. It is a electro-neuro medical diagnostic technique applied to muscle systems and peripheral nerves in particular to nerve injuries and muscle damages. However, the search for advancing its machinery is on for the past two and quarter centuries which were first discovered by Luigi Galvin a way back in 1791.

Recent studies have demonstrated the potential of providing multichannel recordings of intramuscular EMG Writer`s cramp [1-5]. Intramuscular micro recording has the ability to record from deep muscles without cross talk. Such approaches have included conventional EMG methods [6,7] and multivariate statistical multiscaling methods for multidimensionality [1-10]. Remarkably, intramuscular EMG obtained from Implantable myoelectric Sensors (IMES) in the flexor aspect of forearm were used simultaneously to

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control dexterous hand muscles. In this study, we performed multivariate statistical signal processing techniques. Five electrodes are implanted in to the right-hand (RH) and subject instructed to inscribe with left-hand (LH) this has mainly to see the mirror objects (mirror movements) of right hand while writing with LH.

Writer`s Cramp

Writer‘s cramp (WC) is a task-specific commonest focal dystonia of the hand was explained 200 years prior to primary torsion-dystonia [11]. It is a disorder caused by muscle spasms of the flexor aspect of forearms occurring during performing fine motor tasks, such as writing and playing instrumental music (WC, Musician`s cramp, etc) [12]. It is also referred to as scriven-er`s palsy and mogigraphia.

Dystonia

Dystonia is a disorder causing variable muscle tone and frequent dexterous hand muscle quiver [11], defined as a neurological syndrome characterized by involuntary, continued, patterned, and frequently repetitive muscle contractions of differing muscles, causing caricature movements or irregular postures [12].

EMG in writer’s cramp

Typically, EMG) is used for guiding botulinum-toxin (BonNT/Botox) injections into muscles once muscle selection is over. Use of custom-built EMG in selecting muscles for injecting Botox is useful, but is limited by the fact that limited causal EMG sampling may yield limited unrepresentative information. Further EMG findings may be confounded by compensatory movements and local discomfort caused by EMG wires. Therefore, to overcome these issues, microelectrodes are implanted into multiple muscles which can record the EMG during the activation of the dystonia and can provide substantial information on the involvement of deeper or not palpable-muscles. With the, advent of sophisticated imaging signal modalities the organic nature of writer‘s-cramp is no more in doubt.

Clinical features

Occasional subjects may report a history of trauma or strain to the affected limb. Most subjects initially complain of feelings of tension in the fingers or forearms that interfere with the fluency of writing; a minority may also experience pain. Then the pen is held forcefully with anomal-ous excessive contraction (dystonia) of the hand and/or forearm muscles, causing different patterns of deviation from the normal or premorbid pen grip and hand-posture, Writing may begin normally with dystonic posturing occurring after drawing few spirals, a few alphabets or words; In some subject develops dystonia of hand even before commencement of writing, as soon as they reach up to pick the pen. A common pattern of writer‘s cramp involves excessive flexion of the thumb and index finger, with pronation of the hand and ulnar deviation of the wrist.

Methods

A set of five miniature sterilized microelectrodes (100μ, from California Fine Wire Company, USA), were used in each subject. Each subject with Writer‘s cramp was seated comfortably in a specially designed revolving chair for sitting and writing. The electrode sites were found by palpating the muscle during a voluntary contraction and electrodes were inserted into specific-target muscles on identification of the traces on Oscilloscope and neurologist opinion. The skin was always cleaned thoroughly with spirit before the electrode placement. The placements were tested for accuracy, ‗cross-talk‘, bad connections, etc. by requesting the subject to perform several test movements (i.e., putting the particular muscle into action) and test writing (Figure 1 and 2).

Figure 1: Insertion of fine wire electrode in Extensor Carpi Radialis (ECR).

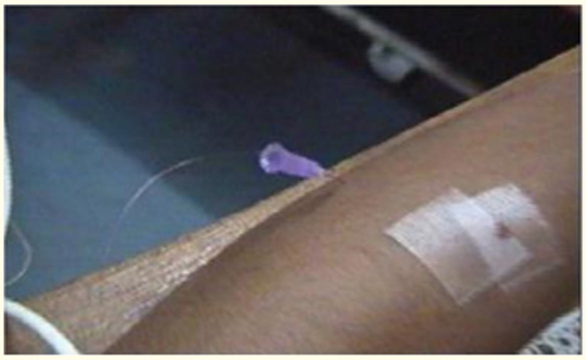

Figure 2: Checking accuracy of the fine wire electrode placement by active muscle contraction.

Later, the electrodes were connected to our indigenously developed 5 channel ‗prototype' ma-chine (Figure 3 and 4) interfaced to the Pentium-III computer. The amplifiers have an input imped-ance of > 200 Mega Ohms and common mode rejection ratio of 58 dB. Each output channel was filtered to remove motion artifact and high-frequency noise using notch band pass filters with cut-off frequencies 0.5 Hz (Lower) and 10 kHz (Upper). A sampling frequency 3 kz/channel was used.

Figure 3: Subject writing after insertion of micro Fig 4 wire electrodes with indigenous EMG prototype.

Figure 4: A close up of writing during signal recording with Indigenously developed EMG prototype.

As most discordant muscle movements are those of wrist, 4 muscles causing flexion and extension of wrist viz, ECR, ECU, FCR, FCU were analyzed in all patients and one more muscle (as decided by the Neurologist, for example, ADP, APL, etc. which showed the maximum discordance of mirror dystonia) on the right hand was included. EMG signals were simultaneously recorded from all five muscles while the patients inscribed with RHWS and LHWS (Figure 5 a, b).

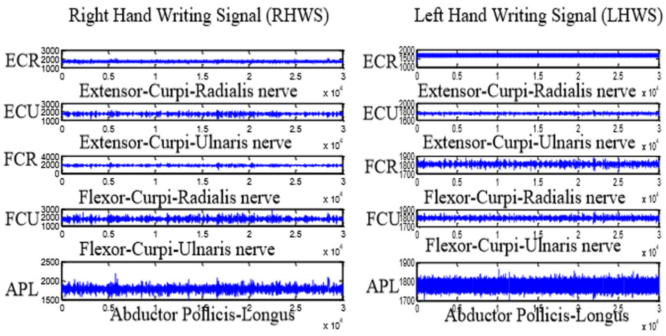

Figure 5:
a. LH muscle signals of Patient 1 D Group
b. RH muscle signals of Patient 1D Group

Multivariate techniques

For a given population of size (N = 12 subjects), the $\sigma 2$ (called variance is the average of the squared deviation of each data point from the mean-value) is mathematically expressed and computed as

$$\sigma^2 = \frac{1}{N}\left[\sum_{i=1}^{N}(x_i - \mu)^2\right] \qquad (1)$$

where (−) is the deviation of each data point from the mean. By squaring the deviations, more weight is placed on points that those points lie away from the mean, further. The is the population parameter and quantifies the dispersion in the entire population of size N. therefore, the variance for a sample is designated by s2 which can be computed differently

$$s^2 = \frac{1}{n-1}\left[\sum_{i=1}^{n}(x_i - X)^2\right] \qquad (2)$$

The covariance was performed. For solving the Eigen vectors, in our computation, we adopted the Jacobi method is a method of solving a tridiagonal matrix equation with largest absolute values in each row and column dominated by the diagonal element. Each diagonal element is solved for, and an approximate value plugged in. The process is then iterated until it converges. The algorithm reviewed from numerical algorithms group (NAG) routines and from the numerical recipes in C/C++ text (Cambridge University press [13]), Bath Information and Data Ser-vices (BIDS), University of Bath, UK. Principal component analysis (PCA) requires that the Eigen-values and the covariance matrix be formed. The Eigen-values obtained are unique for the entire set. In fact, it turns out that the

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Eigen-vector with the highest Eigen-value is the principle component of the data set. The Eigen-vector with the largest Eigen-value is the one that will point down the middle of the data. It is the most significant relationship between the data dimensions.

Results and Discussion

In analyzing the standard deviation (SD) of the 5th muscle (selected because of active MM's) – the D group always showed significantly larger SD's with the right hand as compared to the left hand (around 2 to 10 times larger). The following Table 1 gives the statistical significance.

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

Table 1: 5th Muscle Right Hand Writing Signal (RHWS) > Left Hand Writing Signal (> 2 times larger).

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

In the C group the right was larger (>2 times) in 3 out of 8 only and in 1 patient the left was greater than right (> 5 times). This would be consistent with the hypothesis that larger variances occur in the D group because a larger compensatory force is needed to overcome the dystonic force. In the C group the absence of this difference in a majority would suggest that here the difference between the two is absent or minimal. The 12 patients both LHWS and RHWS means (12 * 10 means) are analyzed, using them as primary data (i.e., ignoring the variations within the signals). The purpose is to see whether, on the whole, patients differ in their averages and whether, across patients muscle averages differ, as compared to inherent variability: The computational results of this analysis, is given in the table 2.

Source	$SS/10^5$	df	$MS/10^5$	F—ratio *df of F-ratio p-Value		
Patients	0.1978	11	0.0180	1.9270	11.99	0.0466
Muscles	1.5134	9	0.1682	18.0226	9.99	0.0000
Error	0.9237	99	0.0093			
Total	2.6349	119	-	-	-	-

Table 2: Analysis of variance (anova) for means.
*degree of freedom.

As expected, there is not much evidence of differences between patient averages but there is highly significant difference in the averages for the 10 muscles of 12 patients. A similar analy-sis of variance (ANOVA), carried out on the corresponding standard deviations (i.e., on 12 patients LHWS and RHWS (12 x 10) standard deviations, see figure 3) of signal strength is given in the below table 3.

Source	$SS/10^5$	df	$MS/10^5$	F—ratio *df of F-ratio p-Value		
Patients	0.5033	11	0.0458	3.09	11.99	0.0013
Muscles	0.0915	9	0.0102	0.69	9.99	0.2836
Error	1.4649	99	0.0148			
Total	2.0597	119	-	-	-	-

Table 3: Analysis of variance (*anova*) for standard deviation.
*degree of freedoma

Here, we clearly see that there is large variability among the patients while the variations observed in different muscles are not significant. In other words, more useful information (in the sense of throwing light on the behavior' of patients with Writer's cramp (WC)) can be expected by a probe into variation patterns (AC-component) of the signals than the mean levels (DC-components). Perhaps a study of ‗normal' peoples' data as a control can clarify the matter. In order to see how far the overall information on the Means and SD's of patients can be summarized by a smaller number of ‗scores', singular value decomposition (SVD, essentially equivalent to the principal component analysis (PCA – a latent variate factorial or factor ma-thematical analysis technique)) was carried out on each of the two matrices, i.e., the means and the standard deviations. Correlation between signals from different muscles in the same hand: The correlations, for each patient, between the signals when writing with the right hand and when writing with the left hand though mostly the correlations are negligible, some correlations are quite significant and markedly high. These are significant correlations (i.e., correlations which are greater than (>) 0.50 in absolute value. A further attempt at clustering the 12 WC subjects by using the principal component (PC) scores of their ―differences‖ in counts of signals was made, with the following results: The total sum of squares is 89260 while the first two components account for 68836 = 50219 + 18617 i.e., accounts for about 75% (~ 80%) of the variation in the data. This pair of coordinates give a good enough summary representation of the information conveyed by the distance matrix. The two (centered) principal component scores for the 12 subjects are given in the figure 6.

$$
Pa_2 = \begin{pmatrix} -100.7286 & 4.9914 \\ -135.4948 & 18.6261 \\ 58.9665 & 31.6554 \\ -4.4131 & 0.9095 \\ -80.9136 & 1.0355 \\ -12.1537 & -18.3320 \\ 7.9185 & 8.2583 \\ -49.9930 & 63.3184 \\ 9.2109 & -46.9489 \\ -86.4117 & -27.6721 \\ 37.5296 & 55.9556 \\ 0.8076 & 82.0194 \end{pmatrix}
$$

Figure 6: Principal Component scores of 12 subjects.

A scatter plot of these scores is shown in the in the Euclidean space, which subject is nearer to and other.

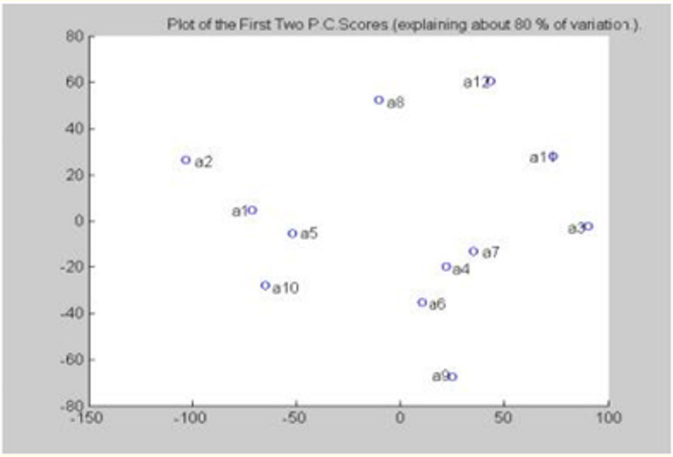

Figure 7: Scatter plot of the First Two P.C. Scores (80% of variation).

From this plot of the first two PC scores of the 12 subjects, the following conclusions are drawn. The points are well scattered out, without clear pattern except for the case of subjects {a6, a4, a7}. These three are near enough to one another as compared to the remaining nine subjects. Indeed, these three seem to form a lineal ordered set (and thus forming ellipsoidal curves or resembling clouds in the space) with a4 coming between a6 and a7. It is also sugges-tive that {a3, a11, a12}, {a10, a5} may form two similar lineal ordered sets, though the distances are much larger than in the case of the first set. Subjects {a8, a9) are isolated and are very far-thest to each other and thus explaining circa ~ 80% variance.

Conclusions

Our study showed significant quantifiable EMG-differences in the signals seen while writ-ing with the right and left-hands between those WC`s patients with C group v/s those with D group. The canonical-variates defined for 2 sets-of-variates observed on the same —individuals|| are pairs of linear-combinations of the two-sets, which are maximally correlated with each other, but uncorrelated with other such sets. In the present case one can construct a combination of RH and LH signals, which have a maximum possible correlation. If the correlation is high-enough, it would mean that two-signal-sets are somehow interrelated possibly the same causal-mechanism being responsible for the signal-patterns in the right and left-hand-signals. Other-wise, the two sets of signals appear to be independent of each other on the whole. The data analyses made in this direction showed some significant findings which led to attempts at more sophisticated analyses multivariate techniques leading to effective data summarization and measures of dissimilarity between patients as reflected in the signals recorded and consequent possible clustering among them. However, these did not lead to any meaningful clinical con-clusions. These analyses could possibly be applied to longitudinal follow-ups and correlations with a normal control population in future to better comprehend the phenomenon of Writer's cramp.

Nomenclature

ECR: Extensor-Carpi-Radialis

ECU: Extensor-Carpi-Ulnaris

FCR: Flexor-Carpi-Radialis

FCU: Flexor-Carpi-Ulnaris

EDC: (ED2)Extensor-Digitorum-Communis-2nd digit fascicle

EPL and EPB: Extensor-Pollicis-Longus and Brevis

EIP: Extensor-Indicis-Proprius

EIL: Extensor-Indicis-Longus

FPL: Flexor-Pollicis-Longus

FPB: Flexor Pollicis Brevis

ADP: Adductor-Pollicis

APB and APL: Abductor-Pollicis-Brevis and Longus

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