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A new methodological approach Based on Stationarity and Permutation Entropy of EMG Bursts for Assessing Muscle Function Alterations in a Parkinson's Disease Animal Model

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INTRODUCTION & AIM

The EMG signal is the electrical manifestation of motor unit (MU) recruitment processes underlying the contractile dynamics of muscle fibers. The analysis methodology frequently carried out includes a preprocessing stage based on artifact removal and stationarity testing, and a feature extraction and interpretation stage. Generally, stationarity criteria are difficult to meet when EMG signals are evoked by momentary activations (bursting activity). Thus, the study and/or characterization of contractile patterns evoked in free-moving protocols require particular treatments.

Aim. We propose a new approach for quantitatively measuring stationarity by using mean, variance and autocovariance test (MVA-test) and the Permutation Entropy for measuring uncertainty degree. This methodology was applied to EMG signals obtained from a Parkinson's disease (PD) lesion model to longitudinally study the muscle function alterations.

METHOD

EMG recordings

Fig. 1 Experimental setup (lateral view) and the animal walking on the treadmill (view from below).

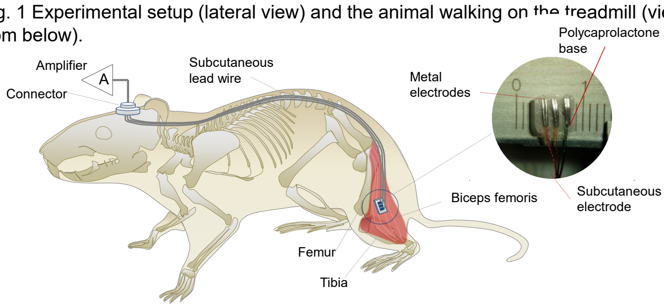

Fig. 2 Electrode was implanted in the rat's hindlimb under general anesthesia. The wires of the electrode were conducted subcutaneously to the connector implanted in the head. Biceps femoris muscle is represented in red. The electrode is represented inside the circle at the top of the figure.

Stationarity analysis

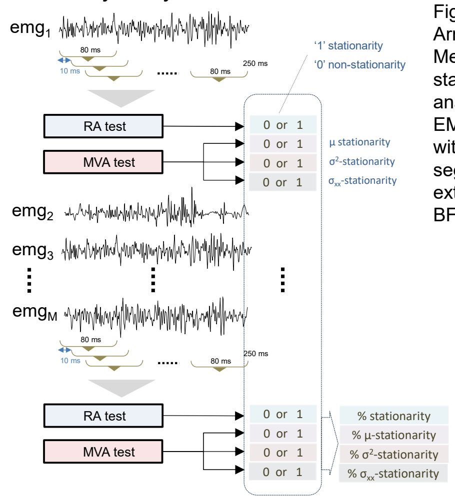

Fig. 3 Implementation of the Reverse Arrangement test (RA-test) and the Mean, Variance, and Autocovariance stationary test (MVA-test). The analysis was conducted on the BF EMG activity using 80 ms segments with a 10 ms step. Additionally, segments ranging from 10 to 250 ms, extracted from the area of maximum BF EMG activity, were analyzed.

RESULTS

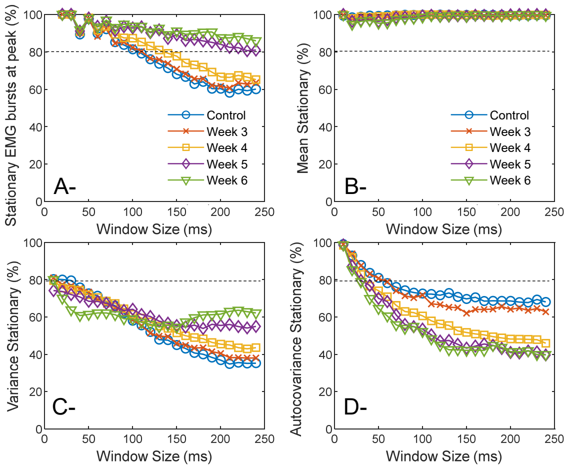

Fig. 4 Percentages of stationarity obtained with the RA- and MVA- tests applied to temporal windows ranging from 10 to 250 ms. The temporal windows were centered on the area of maximum activity of the BF EMG. A) Percentage of stationarity obtained with the RA-test for all animal conditions. Computation for the 10 ms segment was not conducted as it is not possible to compute the z-score of eq. 1. B) Stationarity percentage of mean obtained with the MVA-test for all animal conditions. C) Stationarity percentage of variance obtained with the MVA-test. D) Stationarity percentage of ACvF obtained with the MVA-test.

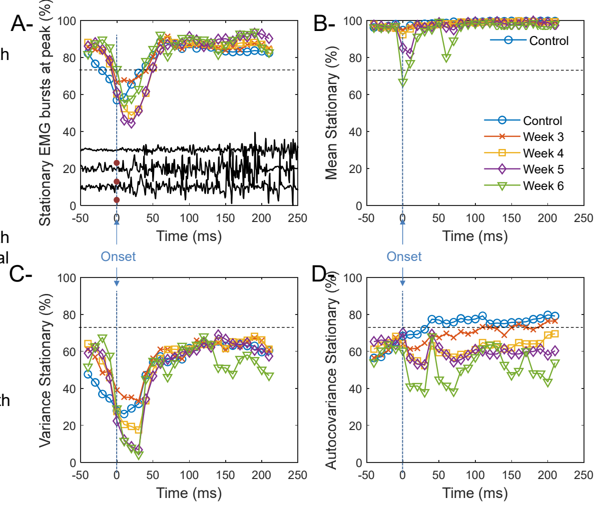

Fig. 5 Percentages of stationarity obtained with the RA- and MVA- tests applied to sliding windows of 80 ms, with 10 ms increments, throughout the contractile dynamics of the BF muscle. A) Percentage of stationarity obtained with the RA-test for all animal conditions. B) Stationarity percentage of mean obtained with the MVA-test for all animal conditions. C) Stationarity percentage of variance obtained with the MVA-test. D) Stationarity percentage of ACvF obtained with the MVA-test.

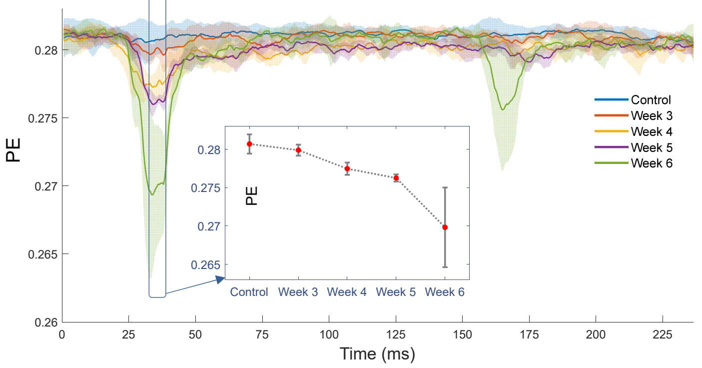

Fig. 6 Permutation Entropy values (PE) obtained throughout the contractile dynamics of the BF muscle. PE values were obtained from sliding windows of 10 ms in consecutive steps (delay = 1). The order of the ordinal patterns used was equal to 7.

CONCLUSION

The analysis proposed allowed for a longitudinal characterization of muscle function alterations in an animal model of PD in terms of the stationarity properties of EMG signals. Furthermore, it was observed that permutation entropy could serve as a robust biomarker for quantifying neuromuscular remodeling caused by PD progression.