

SPECTRAL ANALYSIS OF PHYSIOLOGICAL FORCE TREMOR DURING DYNAMIC MOVEMENTS OF RAT SKELETAL MUSCLE

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ABSTRACT

The purpose of the present paper is to describe the use of spectral analysis to characterize normal physiologic tremor derived from dynamic hind limb movements performed by rats. Rats were trained using operant conditioning to repeatedly lift a weighted ring for food rewards. Reaction forces and vertical displacement of a ring assembly were recorded for each lifting and lowering response in real time. Power spectra and spectrograms were generated from the resultant force-time signatures to reveal the normal physiologic tremor associated with muscle activity.

INTRODUCTION

Tremor is the regular oscillation of force output caused by alternating contractions of opposing muscles. Like recordings of EMG, analysis of physiologic force tremor has been useful for the study and diagnosis of various disorders affecting motor control processes with humans [1]. Force tremor also has been recorded reliably from isometric forelimb movements of rats [2]. Spectral analysis can be used as a semiquantitative method for assessing the activity of motor units. For example, frequencies above 6 Hz indicate the range of firing rates, and the power at different frequencies give an estimate of the number of motor units producing it. Frequencies below 6 Hz generally correspond to the mechanical properties of the muscle and soft tissue.

The assessment and study of force tremor (including EMG) has been limited to static exertions involving mostly isometric muscle activity or the isometric portion of a dynamic response. Therefore, important or informative features of motor control (e.g., changes in motor unit recruitment) may be missed by excluding dynamic portions of muscle activity. The ability to characterize tremor during dynamic movements thus can broaden its application in musculoskeletal research and lead to its use as a screening tool for identifying fatigue and/or injury states of skeletal muscle associated with normal activity or strain overload. In the present study, we attempted to use spectral analytic methods to characterize voluntary, dynamic weight-lifting movements by rats.

MATERIALS AND METHODS

Male Sprague-Dawley rats (20-weeks; 400 grams) were trained with operant conditioning techniques to perform a hind limb weight-lifting response for food rewards. Using a standard operant chamber and custom-designed lifting apparatus, each rat was trained to enter a tube, stand on a force plate, insert its head and neck into a ring, and lift a weighted, 700-g ring assembly approximately 2.5

cm until its nose broke an infrared beam. Food pellets were delivered following each successful lift and could be retrieved by exiting the tube. Most rats completed 80 responses in less than 2 hr.

Force measurements (including weight of the rat) were taken beneath the force plate with a 10-lb load cell, and vertical displacement of the yoke was measured with a LVDT. Force and displacement were sampled at 500 Hz, low-pass filtered (corner frequency = 100 Hz), and amplified. The force-time signal was used for spectral analyses using MATLAB (Mathworks).

RESULTS

Results from two representative lifting and lowering movements are shown in Figure 1. In both examples, forces were elevated in the period preceding positive ring displacement and peaked during or near maximum displacement. The force bursts seen in the example on the right correspond with several small displacements of the ring and could represent “attempts” to lift the ring assembly. Spectrograms in the third panels reveal that the power of frequencies above approximately 6 Hz become more pronounced during periods corresponding to the increases in force and displacement, suggesting an increase in motor unit firing rates at those times. The power spectra reveal multiple frequency peaks, but generally were less informative in this context than the time-series plots.

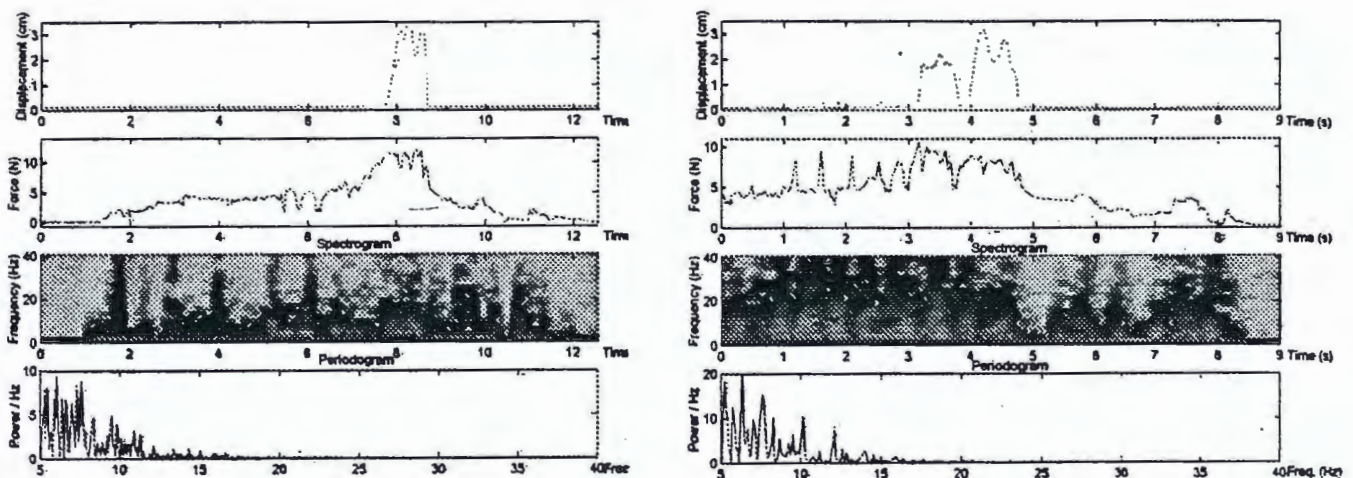


FIGURE 1. Plots of displacement (cm) and force (N) across time (s) and associated spectrograms and power spectra for two representative responses.

DISCUSSION

Spectrograms can reveal important subtleties in the dynamics of voluntary muscle activity, and thus can supplement force and displacement data. Together, these methods can be used to reveal patterns of motor unit activity during ongoing movements. Power spectra may be useful if they are generated separately for discrete phases of the dynamic movement. Assessing force tremor also has several advantages over surface EMG. EMG spectra can be confounded by covarying electrical phenomena, such as changes in conduction velocities of muscle fibers, motor unit action potential, the number of motor units firing in proximity to the electrode, and the recording conditions, especially with nonstatic movements. Results suggest that spectral analysis techniques may be useful for assessing musculoskeletal fatigue or injury following different work exposures.

REFERENCES

- 1 Homberg, V, K Reiners, H Hefter, H-J Freund The muscle activity spectrum: Spectral analysis of muscle force as an estimator of overall motor unit activity. *Electroenceph Clin Neurophysiol* 1986; 63: 209-222
- 2 Stanford, JA, E Vorontsova, SC Fowler The relationship between isometric force requirement and forelimb tremor in the rat. *Physiol Behavior* 2000; 69: 285-293

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