ASSESSING REGULARITY IN VOLUNTARY MOTOR ACTIVITY WITH APPROXIMATE ENTROPY

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INTRODUCTION

The objectives of the present study were to: 1) extend the use and analysis of the regularity statistic *approximate entropy* (ApEn) [2] to voluntary motor performances of rats, and 2) describe how ApEn changes as a function of other biomechanical measures of motor performance including pull force and power spectral density. Because previous studies have shown that vibration affects muscle activity [1], we also attempted to determine how a mechanical stressor (i.e., vibration) affects motor activity and thus ApEn.

METHODS

Eight rats were trained with operant conditioning techniques to perform a voluntary and repetitive bar-pulling response [3]. After training, a single 5-hr exposure session was conducted in which food rewards were earned for performing pull-bar responses of at least 1-s duration and 0.1 N peak force. For one half of the rats, a vibration stimulus (125 Hz, 49 m/s^2) was applied to the pull bar with every response. Because thousands of bar-pull responses were performed by each rat, 4 to 7 bar pulls of at least 2-s duration were sampled at 1000 Hz in each successive 30-min time bin of the session. To eliminate any signal noise from the vibration stimulus, the vibration was turned off briefly during the recording of those forces.

Among the record responses, several time-domain measures were computed, including peak force, mean force, and standard deviation of the force-time series. In addition, a Matlab routine was developed to calculate ApEn for each response on the basis of an algorithm previously published [2]. The force-time series for each response was truncated, and only the middle 1024 data points were used in the calculation of ApEn. In addition, the power spectral density (PSD) was computed to obtain the total power of the force-time series of each response. The total power of the spectrum was calculated as the integral of the PSD between 5 Hz and 40 Hz – the range often associated with physiological force tremor. The modal frequency also was determined from that range. ApEn and the other time-domain measures were compared and plotted as a function of exposure group and session time.

RESULTS AND DISCUSSION

All rats were trained successfully to perform repetitive bar pulls for food rewards with or without vibration. 3-5 thousand bar-pulling responses were generated in the 300-min session with each rat with and without the vibration stimulus. Global measures of performance, including peak force, mean force, and standard deviation of the force-time series, total power, the modal frequency, and ApEn, when averaged across the recorded pull-bar responses, revealed no significant differences between the vibration and no vibration groups. In both groups, however, there was a significant decrease in pull force, total power, and ApEn. Furthermore, orderly relations were found when ApEn was compared with other measures. For example, Figure 1 shows significant positive correlations between ApEn and pull force and, in the vibration group only, the slopes of the functions that describe the relation between ApEn and force significantly decreased across session time. Additional results (not shown) indicated similar relations between total power and force. Increases in ApEn were associated with increases in total power; however, the relation between ApEn and total power did not change across session time. The time-dependent decreases in ApEn and changes in the functions relating ApEn to force and total power in the vibration group indicate that regularity in each force-time record increased with increased exposure to the repetitive task and that vibration may have exacerbated this change. It is tempting to speculate that a physiological response such as tremor or fatigue might have played a role.

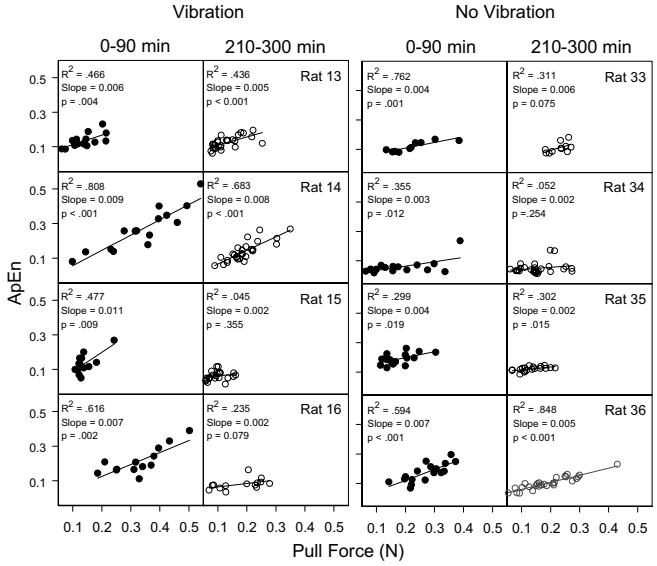

Figure 1. ApEn for the vibration and no vibration groups in the first and last 90-min periods of the session plotted as a function of pull force.

CONCLUSIONS

The present study demonstrated that high-gain force records obtained from voluntary bar-pull activity of rats revealed systematic changes in ApEn, total power, and other measures of performance. In addition, vibration may have had direct motor effects contributing to changes in force output, and that the regularity statistic ApEn was sensitive to those changes.

REFERENCES

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3. Wirth.O. Proc. 10th Int Hand-Arm Vibration Conf; 2004; 145.