EVALUATION OF FATIGUE IN SYNERGISTIC LUMBAR MUSCLES USING CROSS RECURRENCE PLOTS

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Introduction: Analysis of the EMG by recurrence plot (RP) and recurrence quantification (RQ) has been found superior to spectral analysis for assessment of the nonlinear time-course of muscle fatigue (Ikegawa et al. 2000). The purpose of the present study was to extend RP analysis to evaluate the simultaneous time-course of back-muscle fatigue in synergistic lumbar muscles using cross RP (CRP) and RQ.

Methods: Nine male subjects (age range 21-27 years; three rowers, three volleyball players and three sedentary subjects) completed the endurance test of Biering-Sorensen. Each subject was challenged to maintain posture of the unsupported upper-body torso without motion in the prone position. The lower body (below waist) was positioned on a 15 degree inclined table. Upon command, the subject extended his back to a horizontal position and held this posture as long as possible. After a 4-min recovery period was completed the entire test procedure was repeated. Simultaneous EMG recordings were obtained from the left and right lumbar muscles by bipolar electrodes at level L3. The EMG time series obtained from the symmetrical left and right synergistic muscles were embedded in the common 10 dimensional phase space of the CRP. Also individual RPs of single muscle EMG data was calculated. All CRPs and RPs were subjected to RQ analysis (Procalysis® nonlinear time series analysis software package, www.simplana.de).

Results: Mean time to task failure decreased in the second test from 164s to 144s in the sedentary subjects, from 201s to 167s in the volleyball players, and from 352s to 295s in the rowers. All CRP revealed distinct pattern transitions and the respective RQ analysis identified nonlinear time evolutions of recurrence parameters. By comparing CRP with the single muscle RPs it was possible to differentiate individual contributions of the synergistic muscles to the entire dynamics.

Discussion: CRP analysis has been found appropriate to investigate the relationship of synergistic lumbar muscles subjected to the same fatiguing task. We conclude that this nonlinear assessment of EMG patterns obtained from muscles participating simultaneously in an integrative task can give a holistic account of the nonlinear development of physiological fatigue.

Keywords:
nonlinear, recurrence, fatigue

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