RELATIVE TIMING OF MUSCLE FATIGUE AND COORDINATION CHANGES DURING REPETITIVE DUMBBELL LIFTING

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INTRODUCTION

Repetitive stress injuries (RSI) affect tens of thousand Americans each year and are very costly, with some estimates of the yearly total costs nearing a billion dollars (Webster & Snook, 1994). For repetitive tasks, muscle fatigue is often associated with altered movement coordination and some of these altered movement patterns may lead to the development of RSI (Mizrahi et al., 2000). While some studies have examined coordination patterns pre- vs. post-fatigue, no study has yet examined the time course over which muscle fatigue and movement pattern changes manifest themselves. The goals of this study were to determine, for a repetitive upper extremity task, (1) if changes in muscle fatigue and coordination progress monotonically and (2) if changes in muscle fatigue precede changes in coordination.

METHODS

Six healthy right-handed male subjects (age 23.7±4.2) gave informed consent before participating. Subjects performed dumbbell rows with 6% of their max isodynamic lifting strength at 40 lifts/min until volitional exhaustion. The test was repeated for each arm about one week apart, in random order.

3D motions of 12 reflective markers placed on the torso, upper arm, and forearm were recorded at 60Hz (Vicon-612, Oxford Metrics, Oxford, UK). Inverse kinematic analyses were performed and Cardan angles for shoulder flexion, abduction, and rotation were calculated. Maximum angles for each lift were extracted from these data.

Eight bipolar surface electrodes (Delsys Inc, Boston, MA, USA) recorded EMG from the biceps brachii; pectoralis major (clavicular portion); anterior, medial, and posterior deltoids; upper and mid trapezius; and latissimus dorsi at 1080Hz. The median frequency (MdPF) for each muscle for each lift was calculated as a measure of fatigue status. Cross correlations between MdPF and maximum joint angles were computed to determine the temporal sequencing of fatigue and movement pattern changes.

RESULTS

Subjects averaged 401±83 lifts with their right arm and 382±46 lifts with their left. This was consistent with findings that the dominant arm is usually more resistant to fatigue (Tanaka et al, 1984). Shoulder flexion and rotation and elbow flexion angles remained consistent across trials. Shoulder abduction motions were much more variable (Fig. 1). Unlike isometric or single degree-of-freedom fatiguing tasks, changes in kinematics and EMG activity were not monotonic for this multi-joint task.

Variations of max shoulder abduction and mid-trapezius MdPF for a typical subject are shown in Fig. 2. Cross-correlation analysis yielded a negative correlation (r = -0.599) at a negative lag (-20 lifts). This indicates that for this subject, changes in muscle fatigue states occurred about 20 lifts before changes
DISCUSSION

During multi-joint movement tasks, humans can and do alter their inter-segmental movement patterns while maintaining constant output to offset the effects of muscle fatigue (Côté et al., 2002). Our results indicate that changes in kinematics and fatigue states were not monotonic, but varied continuously during each trial. This finding was highly consistent across all subjects. Cross-correlation analyses also demonstrated that shifts in coordination often depended on specific changes in muscle fatigue state. However, these nature of these changes varied widely across subjects.

Differences in correlations may result from different subjects using different strategies to compensate for muscle fatigue. Changes in coordination at any one joint may also result from a more complex combination of changes in fatigue state across multiple muscles simultaneously. Future research will be aimed at clarifying these issues.

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REFERENCES