UPPER EXTREMITY MUSCLE FATIGUE THAT INDUCES MUSCLE IMBALANCES DOES NOT INCREASE MOVEMENT INSTABILITY

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INTRODUCTION

Asymmetric motions are common in the workplace [1] and may cause differential repeated loading of joints and muscles. The diverse demands on the muscles surrounding a joint may cause them to fatigue at different rates and to different degrees [2]. Muscle fatigue leads to decreased force production [3]. This could create a force imbalance around the joint, which could lead to abnormal stress distributions [4] within the underlying tissues, resulting in inflammation. Strength imbalances could also lead to movement instability, which could further increase injury risk. The purpose of this study was to determine if local fatigue of the shoulder flexors could generate a muscle strength imbalance about the shoulder and if this would impact the body's ability to maintain stability of the shoulder motion during a repetitive work task.

METHODS

20 healthy right-handed (25 ± 2 years) subjects sat in an adjustable chair with seat belts to help them maintain constant posture. They then pushed a low weight (10% MVC) back and forth along a low friction horizontal track in time with a metronome for 5 minutes (Pre-Test; Fig. 1A-B). Subjects then performed either a repetitive lifting task designed to fatigue the shoulder *flexors* for 3 minutes (LIFT; Fig. 1C) or the same sawing task with 25% MVC for 4 minutes (SAW; Fig. 1B). They then performed the same sawing task for an additional 5 minutes (Post-Sawing). 3-D movements of the arm and trunk were recorded continuously at 120 Hz using VICON. The three rotational angles of the shoulder were calculated using Euler angles. EMG data were collected at 1080 Hz from 9 arm and trunk muscles. Maximum force measurements (MVCs) were taken at various points throughout the trial (Fig. 1A). These included shoulder flexion, extension, internal rotation, and external rotation strength. EMG instantaneous mean power frequencies (IMPF) were calculated to quantify muscle fatigue [5].

Local dynamic stability [6] was quantified using short-term local divergence exponents (λ_s*) which indicate the rate of divergence of neighboring trajectories. Positive exponents indicate local instability, with larger exponents indicating greater instability [6]. λ_s* was calculated for the shoulder, elbow and wrist pre and post-fatigue. λ_s* values were compared using 2-factor (Pre/Post x Lift/Saw) within subjects ANOVAs. MVC values were first normalized to % maximum MVC and compared using 2-factor (Time Point (1-4) x Lift/Saw) within subjects ANOVA.

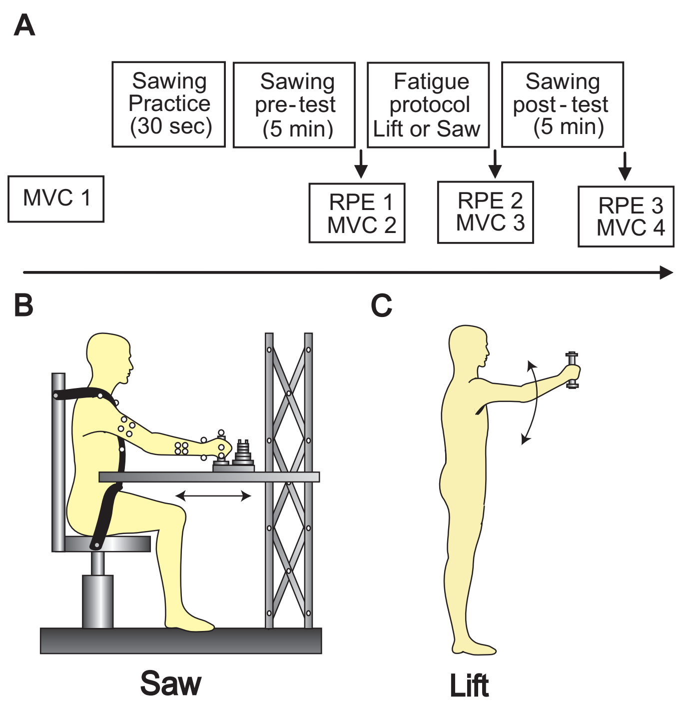

Figure 1: Experimental procedure

RESULTS AND DISCUSSION

Subjects exhibited significant muscle fatigue. This is evident in the decreases in IMPF (Fig. 2) and muscle strength. Strength decreases in shoulder flexion, extension, and internal, external rotation were all significant ($p < 0.006$). The muscle strength also became slightly more unbalanced as a result of targeted fatigue of the shoulder flexors (Fig 3). λ_s* tended to decrease for shoulder and elbow movements (Fig. 4). This decrease was only significant for shoulder motion after the lifting task ($p = 0.035$).

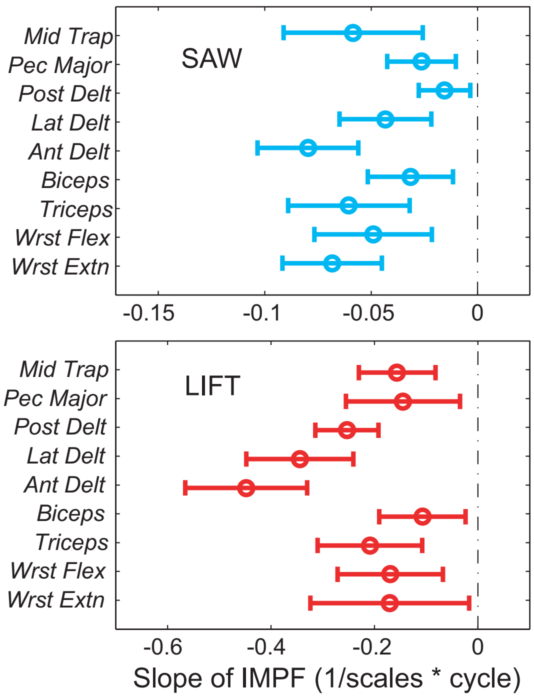

Figure 2: The instantaneous mean power frequency of the EMG decreased over the fatigue task in all muscles tested.

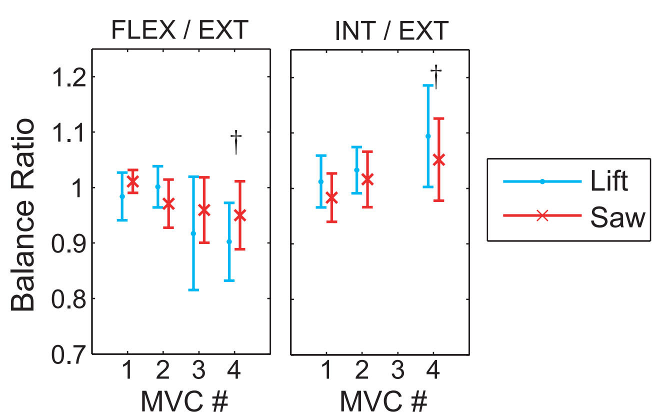

Figure 3. The ratio of shoulder flexion to extension strength decreased after the lifting task ($p < 0.05$), while the ratio of internal to external strength increased ($p < 0.05$). No changes in muscle balance were seen after the sawing task.

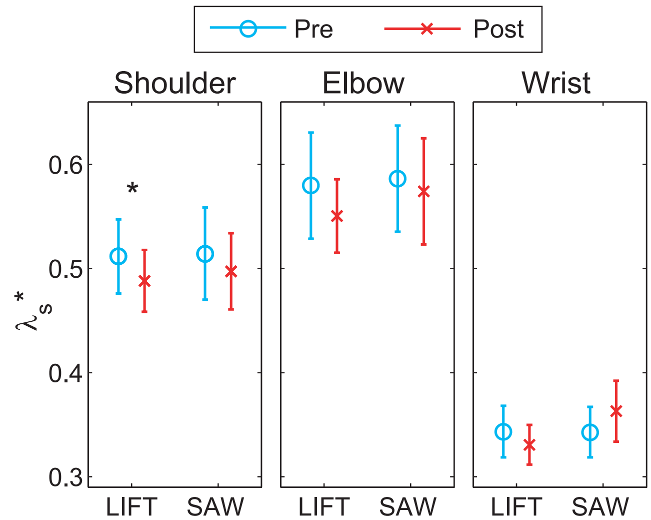

Figure 4: Movements at the shoulder became more stable after fatigue. This change was significant after lifting ($p = 0.035$) but not sawing ($p = 0.241$).

CONCLUSIONS

Subjects performed consistently accurate movements before and after fatigue (Not shown). Fatigue led to decreased muscle strength and increased muscle imbalance. Fatigue also led to increased movement stability. This result suggests that after subjects fatigued, they may have needed to apply greater control to their shoulder movements. Therefore, subjects can compensate for muscle fatigue while performing multi-joint redundant tasks, in ways that maintain both movement stability and task precision.

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