FATIGUE SPECIFIC INFLUENCES ON MOTION STRATEGIES: A PRINCIPAL COMPONENT ANALYSIS OF KINEMATIC LIFTING WAVEFORMS

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INTRODUCTION
Manual materials handling, specifically lifting, and the link to musculoskeletal disorders and injury has been previously investigated; however, the mechanisms of injury remain unclear [1]. The effects of fatigue on motion patterns have suggested a compensatory shift toward a more biomechanically compromising but less physiologically demanding motion [2,3]. This study investigated the differences in lifting motion strategies as a result of general global fatigue, and joint specific shoulder and back fatigue.

METHODS
Thirty-one healthy university students (16 males and 15 females; mean age 24 years, height 172 cm, weight 72 kg) were recruited to complete three lifting sessions: general (global) fatigue, back specific fatigue and shoulder specific fatigue. The lifting task used in pre-post lifting assessment and the general protocol involved lifting and lowering a crate, weighing 10% of their maximum lift capacity, from floor to shoulder height at a rate of six lifts per minute. Pre and post static shoulder and back maximum voluntary contractions (MVCs) were recorded to provide an indication of global back and shoulder fatigue. The general fatiguing protocol required participants to lift continuously for 75 minutes, the specific fatigue protocols required 5 minutes of lifting pre and post to the fatiguing protocol. The back specific fatiguing protocol consisted of a modified Bierring Sorensen test, ten second horizontal back extension hold with five seconds rest between repetitions to fatigue. The shoulder specific fatiguing protocol consisted of a repeated seated mock lift at a rate of thirty lifts per minute from hip to shoulder height to fatigue, using a weight 40% of the shoulder MVE. Trunk motion and upper extremity motion (bilateral shoulder and elbow movement) were recorded using an electromagnetic tracking system (Polhemus Liberty Latus, Vermont, USA), with sensors placed over the sacrum and C7 and T8 vertebrae, as well as the hand, forearm and upper arm, bilaterally.

Processing and analysis of the kinematic data included determination of joint centers and joint angles, extraction and normalization of each lift waveform to 101 time points. Principal Component Analysis (PCA) was used to extract modes of variation and a one way repeated measures ANOVA was used to determine differences between the pre-fatigue, the general fatigue, the back specific and the shoulder specific fatigue states.

RESULTS and DISCUSSION
For all testing sessions there was a significant decrease in the shoulder and back MVCs (p<0.001), indicating fatigue. Comparisons between the pre-fatigue lifting waveforms and post-fatigue as a result of specific fatiguing protocol are as follows: General Fatigue Protocol. A late phase variance with an increased elbow flexion coinciding with an increased shoulder flexion during the mid-lift with decreased flexion during load placement and an overall trunk angle decrease was seen with fatigue. These changes in motion pattern suggest that when globally fatigued the shoulder joint is limiting motion. Shoulder Fatigue Protocol. A significant early and mid phase difference in the elbow angle coinciding with an early and late phase difference in the shoulder angle was found. Shoulder angle was greater in the load initiation phase and decreased during load placement in the post-fatigue condition. The late phase motion of the trunk was significant with increased extension during load placement. Back Fatigue Protocol. A transition phase variance highlighted by a decrease in shoulder angles was found in post-fatigue waveforms. The trunk angles showed a significant decrease throughout the lift.

CONCLUSION
Joint specific fatigue had a different effect on lifting strategies than global fatigue during repetitive lifting tasks. Shoulder specific fatigue led to a decrease in shoulder joint angles during load placement and an increase in trunk extension. Back specific fatigue led to a decrease in trunk angles and an increase in shoulder motion during transition of the load. Significant compensations were seen in the shoulder and trunk as a result of general fatigue. The shoulder decreased motion during load placement and the trunk increased flexion throughout the entire task.

REFERENCES

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