INTRODUCTION

Fatigue has been shown to influence motion strategies and the subsequent compensations may lead to an increased risk of musculoskeletal disorders and injury [1]. Lifting tasks are complex and multi-segmented, and relative phase has been successful in quantifying inter-joint coordination [2]. Relative phase is unique in its ability to consolidate proximal and distal segment displacement and velocity into a single measure [3]. This study examined the changes in relative phase as a measure of coordination during a prolonged repetitive lifting task.

METHODS

Thirty-one healthy participants (16 males/15 females; mean age 24 years, height 172cm, weight 72kg) were recruited from the university student population. The participants performed a repetitive symmetric lifting task at a rate of six lifts per minute for 75 minutes. The task involved lifting and lowering a crate, weighing 10% of their maximum lift capacity (mean box weight 12.4kg), from floor to shoulder height. Pre and post static shoulder and back maximum voluntary exertions (MVEs) were recorded to provide an indication of global back and shoulder fatigue. 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. Motion data was recorded for 3 consecutive lifts at the beginning of the protocol and again at the end of the lifting session.

Coordination of the upper extremity, forearm and upper arm, and the trunk was assessed through relative phase. All relative phase waveforms were time normalized to 101 time points. Principal Component Analysis was used to extract essential modes of variation with a one-way repeated measures ANOVA used to determine differences between the pre-fatigue (initial lifts at beginning of session) and post-fatigue (final lifts at end of lifting session) relative phase waveforms.

RESULTS and DISCUSSION

There was a significant decrease (p<0.01) in the pre-post shoulder and back MVE measures, indicating fatigue. The upper arm relative to the trunk segment was the only relative phase to show significance between early and late phase lifting waveforms. The first principal component (PC1) was significant in explaining 88% of the overall expected variance (p=0.019). PC1 loaded high around 40% and 65% of the relative phase curves (Fig.1). Throughout prolonged lifting, trunk extension leads the lifting motion. At 40% of the lift, there is a difference in the relative arm flexion moves towards being more in-phase with trunk extension at a quicker rate. The increased rate of movement towards being in-phase between the arms and the trunk continues through transitioning of the box from being lifting up to being moved out towards shelf placement (65% of the lift). The final stage of box placement illustrates a similar pattern in both early and late lifting as the arms and trunk move towards being in-phase as the end range of motion for box placement is achieved.

![Figure 1: PC1 loading curve illustrates significant difference in upper arm and trunk relative phase for early and late lifting curves.](image)

REFERENCES


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