THE INFLUENCE OF INTERACTIONS BETWEEN EXTERNAL TASK DEMANDS IN LIFTING ON ESTIMATES OF *IN VIVO* LOW BACK JOINT LOADS.

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INTRODUCTION

The most commonly accepted mechanical risk factors linked to low back injury include: (i) high force demands; (ii) frequent repetition; and (iii) awkward postures [1]. However, as noted by Gallagher and Heberger [2] these exposures have typically been examined in isolation, and are often assumed to contribute independently to risk of injury. As such, our understanding of the combined effects of different external task demands (e.g. load, speed, and lift asymmetry) on low back joint loading and injury may be limited. Therefore, the motivation for this study was to evaluate interactions between: (a) external load magnitude, (b) movement speed, and (c) symmetry of initial load placement on estimates of *in vivo* low back joint loading during an occupational lifting task.

METHODS

Thirty-four participants with an average [SD] of 9 [10] years of manual materials handling experience (mean [SD] age = 37 [10] years; height = 1.80 [0.06] m; mass = 86 [10] kg) were recruited. The inclusion criteria for participation specified that participants reported that they were free of any known musculoskeletal injury and pain at the time of testing.

Whole-body, three-dimensional kinematic data were measured at 160 Hz using a 10-camera optoelectronic motion capture system (Vicon, Centennial, CO, USA). Sets of four and five reflective markers, fixed to rigid pieces of plastic were secured to the body with Velcro® straps, and used to track the position and orientation of 15 body segments that were modeled. Two in-ground force platforms (FP6090; Bertec, Columbus, OH, USA) mounted side-by-side were used to measure reaction forces and moments between the feet and ground. The analog signals from each force platform were synchronized with the kinematic data, and sampled at a rate of 2400 Hz using Vicon software (Nexus version 1.4, Centennial, CO, USA).

Pairs of pre-gelled surface electromyography (EMG) recording electrodes (3 cm inter-electrode spacing; Medi-Trace, Kendall-LTP, Chicopee, MA, USA) were adhered to the skin, bilaterally, over the following six trunk muscle groups: (i) thoracic erector spinae (~T9), (ii) lumbar erector spinae (~L3), (iii) rectus abdominus, (iv) external abdominal obliques, (v) internal abdominal obliques, and (vi) latissimus dorsi. EMG signals were bandpass filtered (10-500 Hz) and differentially amplified (CMRR > 100 dB at 60 Hz; input impedance > 100 MΩ; TeleMyo 2400 G2 Telemetry System, Noraxon Inc., Scottsdale, AZ, U.S.A.) prior to analog-to-digital conversion at 2400 Hz. Surface EMG signals were collected synchronously with the force platform and kinematic data using Vicon software.

Each participant initially performed three lifting trials (box dimensions; 30.5 x 30.5 x 30.5 cm) that represented a low-demand condition (9.3 kg load, preferred movement speed, symmetrical positioning of load). Once these low-exposure trials were collected, the external demands of the lifting task were sequentially modified by manipulating each of the following parameters using a full-factorial design: (a) magnitude of external load – low = 9.3 kg, high = 24.7 kg; (b) movement-speed –

participants were instructed to either perform the lift in a *"controlled manner"* at their preferred speed or *"as quickly as comfortable"*; and (c) symmetry of initial load placement – the load was placed either in front of participants or at 45 degrees to the left of participants' mid-sagittal plane. Each participant completed a total of 24 lifting trials that were evenly distributed across each of the eight experimental conditions.

Reaction forces and moments derived from inverse dynamics analyses, lumbar spine kinematics, and normalized linear envelope EMG signals were incorporated into a three-dimensional, dynamic, EMG-assisted musculoskeletal model of the lumbar spine to quantify L4/L5 joint compression and shear forces [3]. All trial data were truncated to include only the ascending phase of the lifting motion based on the vertical trajectory of participants' linked-segment model centre-of-mass.

Interactions between the magnitude of the external load, movement speed, and symmetry of initial load placement on peak and cumulative estimates of L4/L5 compressive loading, as well as the normalized peak lumbar flexion angle at the time of peak loading, were evaluated with a within-subject, three-factor general linear model.

RESULTS

Significant two-way interactions between load and speed ($p = 0.0035$), as well as speed and posture ($p = 0.0004$) were revealed in peak measures of L4/L5 compressive loading. Subsequent analyses revealed significantly greater magnitudes of peak compressive loading for fast lifting trials with 9.3 kg of external load compared to the preferred speed ($p < 0.0001$; average difference = 588 N); however, there was no significant difference between the preferred and fast lifting trials performed with 24.7 kg of external load ($p = 0.5586$). Significantly greater magnitudes of peak compressive force were also observed in the high-speed trials with asymmetrical load placement ($p < 0.0001$; average difference = 580 N); however, there was no significant difference observed for the asymmetrical condition ($p = 0.5699$).

A significant three-way interaction between load, speed and posture ($p = 0.0477$) was observed in the cumulative estimate of compressive joint loading at L4/L5. Subsequent analyses of the interaction between load and speed across both symmetrical and asymmetrical load placement trials revealed a significant main effect of load ($p < 0.0001$; average difference = 724.7 Ns) and speed ($p < 0.0001$; average difference = 561.5 Ns) in trials with symmetrical load placement; however, there was a significant interaction between load and speed ($p = 0.0006$) for asymmetrical trials. Tukey's *post hoc* test revealed that both the low- and high-load conditions were significantly different ($p < 0.0001$), although a more pronounced difference (1030.6 Ns) was observed at the preferred movement speed.

A significant main effect of posture ($p < 0.0001$) was revealed in normalized measures of lumbar flexion angle at the time of peak compressive loading; however, there was no significant main effect of load ($p = 0.4297$) or speed ($p = 0.1963$) found. Tukey's *post hoc* test revealed that, on average, participants assumed more lumbar spine flexion at the time of peak compressive loading with asymmetrical load placement ($p < 0.0001$; average difference = 8.5% of full flexion).

DISCUSSION & CONCLUSIONS

Results from this investigation provide strong evidence that known mechanical low back injury risk factors should not be viewed in isolation. Rather, injury prevention efforts need to consider the complex interactions that exist between external task demands and their combined influence on internal joint loading. This non-additive response may be especially important to consider when investigating underlying mechanisms of injury.

REFERENCES

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