Biomechanical Evaluation of a Back-Support Exoskeleton: Effects on Spinal Loading and Muscle Activity in Lifting Tasks

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Summary

The study evaluates the effectiveness of a commercial spring-loaded back exoskeleton in reducing biomechanical load. Using motion capture, EMG, and force platform data, the study assesses changes in lumbar kinematics, assistive torque, and muscle activation in ten participants. Results show that the exoskeleton reduces muscle activation suggesting its potential for mitigate worker strain during lifting.

Introduction

Work-related musculoskeletal disorders (MSDs) are a leading occupational health concern, particularly in occupations that require frequent lifting and carrying of heavy loads [1]. These conditions not only impose a significant financial burden on companies and healthcare systems but also have lasting repercussions on workers' physical and mental well-being. Among them, low back pain (LBP) is one of the main causes of disability worldwide and significantly affects workers' quality of life [2]. One promising approach to mitigate these problems is the use of back exoskeletons, which provide mechanical support and assist movement, thereby reducing stress on the musculoskeletal system [3]. The study focuses on the MATE-XB exoskeleton (Comau, Italy), specifically designed to reduce compression forces at the L5-S1 joint. The objective is to analyze biomechanical load during lifting tasks with and without the exoskeleton. The study specifically focuses on lumbar kinematics and muscle activation to evaluate the exoskeleton's biomechanical impact and its potential benefits in reducing mechanical load on the lower back.

Methods

Ten healthy subjects (8 males and 2 females) participated in the study, performing three lifting tasks with a 10 kg load: squat, stoop, and bilateral lifting. Each task was executed in two conditions: without an exoskeleton (free-body condition, labeled as "No Exo") and while wearing the exoskeleton (labeled as "With Exo"). The device provides lumbar support by generating extension torque during lifting movements through two actuators positioned at the hip level. To assess the biomechanical effects of the exoskeleton, we used: a motion capture system (Qualisys, Sweden) with 12 cameras and 66 passive markers to analyze joint kinematics, wireless electromyography sensors (Cometa, Italy) to record muscle activity from 16 upper-body muscles and a force platform (AMTI, USA) to measure ground reaction forces.

Results and Discussion

Figure 1 shows the flexion angle at the L5S1 joint and the changes in muscle activation of right back muscles during the squat lifting task under both conditions. The reported values are averaged across participants. The figure highlights how the exoskeleton reduces muscle activation on the back, assisting subjects during manual lifting tasks. Specifically, the RMS value decreases by 43% when comparing the exoskeleton-assisted condition to the free-body condition.

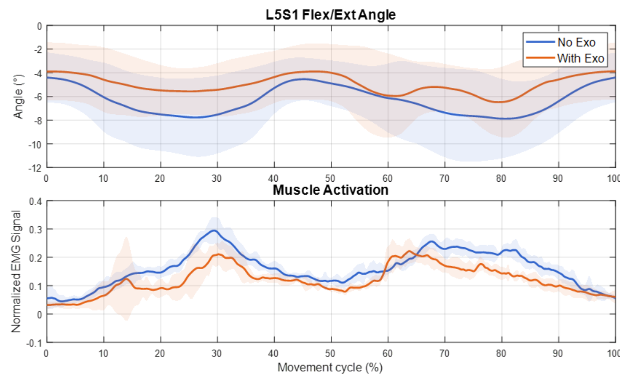

Figure 1: Lumbar kinematics and muscle activation of back muscles during the squat lifting task under free-body (blue line) and exoskeleton-assisted (red line) conditions.

Conclusions

The study introduces a methodological framework for assessing biomechanical load during lifting tasks with a passive back exoskeleton. Findings indicate that the tested spring-loaded commercial exoskeleton reduces back muscle activation, suggesting its potential to alleviate physical strain. Future research will refine the estimation of intervertebral compressive forces through EMG-driven musculoskeletal models [4] and validate these results in more realistic work conditions, such as prolonged use over a work shift, to evaluate long-term effects on worker health and performance.

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References

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