

Effect of Low-Profile, Spring-Powered Exosuit on Back Muscle Fatigue during Leaning

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Summary

We tested six subjects leaning with vs. without assistance from a spring-powered exosuit. We quantified the effect on back muscle fatigue rate. We found that five of the six subjects showed significant reductions in fatigue rate (ranging from 19-85%) for a subset of lumbar muscles (ranging from one to all six recorded muscles) when receiving assistance from the exosuit. These findings suggest that the exosuit may reduce fatigue and improve endurance for individuals who perform extended bouts of leaning (e.g., nurses, material handlers, construction workers).

Introduction

Prolonged leaning and repeated lifting can lead to lumbar muscle fatigue which can have detrimental effects on worker performance, productivity, satisfaction and safety. Wearable assistive devices can reduce lumbar muscle fatigue; however, most wearable devices are limited by practical factors such as affordability, form factor, and their ability to integrate into industrial workflows without interfering [1]. To address these limitations, we previously introduced a new spring-powered exosuit that combines the low-profile benefits of daily clothing with the physical assistance benefits of an exoskeleton [2]. In this study we evaluated the effect of this exosuit on lumbar muscle fatigue during leaning.

Methods

Six subjects (4 male, 2 female, 23.5 ± 1.4 yr., 69.6 ± 7.7 kg., 1.8 ± 0.1 m) performed leaning without, then with, then again without assistance from the exosuit, while holding a 16 kg mass. Lumbar torque assistance provided by the exosuit ranged from 12-16 N/m across subjects. A custom scaffold was designed to ensure consistent leaning posture between trials. Surface electromyography (sEMG) was recorded from six back extensor muscles: bilaterally on the lumbar multifidus (LM), longissimus thoracis (LT), and iliocostalis lumborum (IL). Subjects reported no history of back pain in the past 6 months and gave written consent in accordance with the Vanderbilt University Institutional Review Board. Individual muscle fatigue rate was calculated as the slope of the windowed (1-second epoch) median power frequency (MDF slope) of the bandpass filtered (10-500 Hz) sEMG data. Individual muscle differences in MDF slope across conditions were evaluated using an analysis of covariance (F-test, $\alpha=0.05$).

Results and Discussion

Five of six subjects exhibited significant reductions in MDF slope (ranging from 19-85%) in a subset of muscles with vs. without assistance from the exosuit. Of these five, one showed statistically significant reductions for all muscles, and the

remaining subjects showed significant reductions for two to five muscles. The sixth subject showed a significant reduction in MDF slope for one muscle, and a significant increase for another muscle. Across all 6 subjects, the exosuit significantly reduced the fatigue rates for 20 of 36 muscles analyzed. Previous literature suggests that these reductions in MDF slope may correspond to increased task endurance [3], which may be particularly beneficial for occupations and applications where prolonged leaning is common (e.g. nursing, material/package handling, construction)

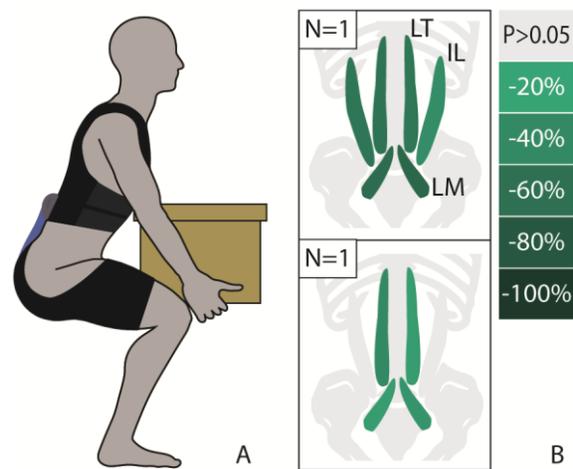


Figure 1: When wearing the spring-powered exosuit (left), subjects (two representative subjects shown) experienced reduced fatigue rates for individual lumbar muscles (right).

Conclusions

We found that a spring-powered, clothing-like exosuit could significantly reduce the rate of lumbar muscle fatigue during leaning. We observed inter-subject variability in the number of muscles that benefited, which specific muscles benefited, and the degree to which each muscle benefited (percentage reduction in fatigue rate) from wearing the exosuit prototype. These findings suggest that this type of exosuit may be effective for reducing the lumbar fatigue of individuals who perform bouts of leaning (e.g., dentists, nurses, assembly line workers and construction workers).

Acknowledgments

This work was supported by an NSF Graduate Research Fellowship (2016201028) and a Vanderbilt Discovery Grant.

References

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