A passive back support exoskeleton can reduce fatigue related changes to the low back in a complex repetitive lifting task

Emma J. Ratke[1], Hannah McMaster[1], Chris L. Vellucci[1], Dennis J. Larson[2], Michael W.R. Holmes[1], Shawn M. Beaudette[1]
[1]Department of Kinesiology, Brock University, St. Catherines, Canada
[1]Kinesiology & Health Sciences, University of Waterloo, Waterloo, Canada
Email: sbeaudette@brocku.ca

Summary

Exoskeletons are an emerging technology which can reduce the physical demand required to perform lifting tasks. This study evaluated the effect of a passive back-support exoskeleton (BSE) in a complex, multiplanar repetitive manual materials handling (MMH) task. Participants completed a multiplanar MMH task for 60-minutes with and without a passive BSE (HeroWear Apex 2). Full body kinematics and trunk and shoulder surface electromyography were collected for 60-minutes. The BSE was effective in reducing markers of physical demand during the task and increased productivity markers. Movement coordination and coordination variability differed between conditions with increased shoulder-lumbar variability and decreased thorax-pelvis variability in the exoskeleton condition. The BSE significantly reduced lumbar erector spinae muscle activity asymmetrically. These findings generally support the idea that a passive BSE is effective in altering indicators of fatigue, more research is needed before recommending their widespread adoption across diverse occupational tasks.

Introduction

BSEs are an emerging assistive technology designed to offload the demands of the back and hip extensor muscles [1,2]. BSEs have primarily been tested in constrained, symmetrical lifting tasks, which are not always representative of MMH tasks. The aim of this work was to gain insight into the ability of a BSE to mitigate fatigue related changes in a complex MMH task. We hypothesized that paraspinal muscle activity would decrease, while trunk flexor muscle activity would increase, and movement variability would decrease.

Methods

Participants (n = 14; 4 female) completed a multi-planar lifting, transferring, and lowering task for 60 minutes with and without a passive BSE (HeroWear Apex 2). Participants were instrumented with surface electromyography (EMG) sensors (Noraxon, Ultium; fs = 2000Hz) bilaterally on their lumbar erector spinae (LES), rectus abdominis (RA), external obliques (EO), and anterior deltoids (DELT). IMU sensors (XSens, Awinda; fs = 60Hz) were used to capture shoulder, pelvis, and thorax joint angles which were used to calculate mean absolute relative phase, and deviation phase for the thorax-pelvis and shoulder-lumbar joint couplings. Rate of perceived exertion (RPE) was collected every 5 minutes. Kinematics and EMG data were collected for 60 minutes continuously. Data were partitioned into 10-minute time bins and analyzed to reveal differences across time and between conditions.

Results and Discussion

The BSE significantly decreased ratings of perceived exertion ($p < 0.0001$) (Figure 2). Participants exhibited faster task completion times in the exoskeleton condition ($p = 0.0095$). Both movement coordination and coordination variability differed between conditions with increased shoulder-lumbar variability ($p = 0.0467$ - $<.0001$) and decreased thorax-pelvis variability ($p = 0.0281$) in the exoskeleton condition. Additionally, the BSE significantly reduced lumbar erector spinae muscle activity asymmetrically ($p < 0.0001$).

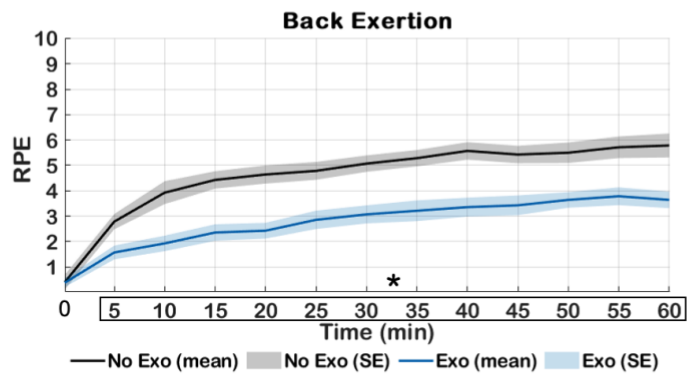

Figure 2: Ratings of perceived exertions (RPE) in the back across time and condition. Asterisks (*) indicate significant differences across timepoints and between conditions for the respective plots.

Conclusions

These findings generally support the ability of a passive BSE in mitigating fatigue-related changes in movement strategies during an ecologically relevant and unconstrained complex MMH lifting task. More research is needed to investigate various models of BSEs and different assistance levels to truly grasp the effect this emerging assistive technology has on human movement and its implications for injury risk.

Acknowledgments

This project was funded by the Natural Sciences and Engineering Council of Canada (Discovery Grant (S. M. B.); USRA (E.J.R.) and the CSA Group Undergraduate Research Scholarship (E. J. R.).

References

[1] Lamers and Zelik (2021). *Wear Technol.* **3**
[2] Toxiri et al., (2019). *IISE Trans. Occup. Ergon. Hum. Factors* .**7**:237